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ENGINEERING

Research Laboratories

MONTANA STATE UNIVERSITY, BOZEMAN

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DRAINAGE CORRELATION RESEARCH PROJECT

Interim Report #1

SELECTION OF SMALL WATERSHEDS FOR HYDROLOGIC STUDY

by T. T. Williams

I. Introduction

The Drainage Correlation Research Project, a study being conducted by the Civil Engineering Department at Montana State College, and sponsored by the Montana State Highway Department and Bureau of Public Roads, is an investigation of peak discharges from small watersheds in Montana. A major phase of the investigation is the comprehensive study of four small watersheds. Continuous records are being obtained at selected locations on the watersheds, of precipitation, air and soil temperature, soil moisture, wind speed and wind direction. Water stage recorders have been installed on the four watersheds, and continuous streamflow data have been recorded since August 1963.

This report describes the selection of the study watersheds. Criteria used in their selection are presented, as well as descriptions of all watersheds which were considered.

II. Method of Selection

The original Prospectus for the project envisioned the instrumentation of three small watersheds in Montana. Selection of the three watersheds was one of the first problems considered when the project was approved in May 1963. Conferences were arranged in June 1963 with Hydraulics Division personnel of the State Highway Department, with engineers of the U. S. Geological Survey, and with the state climatologist of the U. S. Weather Bureau. Out of these early conferences, remarkable agreement of thinking was evidenced by the three organizations noted and by the college personnel involved, on the following points:

1. The addition of a fourth watershed would greatly enhance the results to be obtained from the study, and permit a more representative sampling of Montana's hydrologic areas.

2. The bulk of Montana's peak flow problems have occurred east of the continental divide, and the watersheds should all be located east of the divide.
3. The watersheds to be studied should be selected from among the 161 crest-stage gage watersheds previously established by the U.S.G.S. (Note - this number had increased to 214 by June 1963).
4. Ideally, the four watersheds (if addition of a fourth watershed could be accomplished) might be located as follows: One watershed in the Miles City-Glendive-Circle badlands area; a second on the Marias, Milk, Teton or Sun River drainages; a third in the Harlowton or Lewistown areas; and a fourth on the middle Yellowstone in the vicinity of Billings.

Authority to add a fourth watershed to the study was requested from the State Planning Survey Director on July 19, 1963. On September 11, approval was granted by the U. S. Bureau of Public Roads.

A meeting was held with the State District Engineers, describing what was proposed, and requesting suggestions for watersheds that should be included in the study. Some watersheds were suggested at that meeting, and these were added to the list of watersheds to be inspected.

A total of 13 watersheds were inspected personally by the project supervisor. In most cases he was accompanied by a student technical assistant. U. S. Geological Survey topographic maps were obtained for each watershed and studied prior to the inspections. In most cases, visits were made to local Soil Conservation Service offices prior to the inspections, to examine aerial photographs of the watersheds and discuss the areas with SCS personnel.

Features of each watershed noted during the inspections included the following:

a. Location of watershed
b. Areal extent
c. Type of terrain (i.e., gently rolling, steep canyons, etc.)
d. Predominant land use or vegetal cover
e. Slopes and elevation range
f. Soil types (at several watersheds, soil samples were obtained, and grain size distribution and plasticity index determinations made in the laboratory later).
g. Evidence of irrigation, stock ponds, etc.
h. Accessibility (i.e., roads, trails, etc.)
i. Locations of ranches or habitations in the area.

III. Rejected Watersheds

Brief descriptions of the watersheds inspected and rejected, together with reasons for their rejection, follow.

1. Alkali Creek near Heath (12 miles east of Lewistown). This is a watershed of 3.76 square miles, nearly circular in shape, mainstream running northwest to southeast, with several well-defined tributaries. Alkali Creek is a tributary of McDonald Creek, which eventually drains into the Musselshell River. The basin is moderately steep, lying between 5000 and 6000 feet in elevation. Some active erosion is evident along the streams. The basin is lightly timbered (about 10 to 15 percent) with scrub pine, and about 5 percent is cultivated in hay and grain. The remainder is in native grasses. Silt and stony loams are predominant, with rock outcrops common. Accessibility is adequate, and there are 3 or 4 farms in the area.

The basin was rejected primarily because of its small size. A general storm in the Lewistown-Harlowton area in June 1962 produced 757 cfs on this watershed (201 cfs per square mile).

2. Bear Canyon Creek, Logger Creek, Pitcher Creek, Squaw Creek near Bozeman.

These four watersheds were considered early in the investigation, when it was felt it might be desirable to include a mountainous watershed. The idea of including this type of basin was abandoned when it became apparent that the Hydraulics Section of the State Highway Department had greater interest in watersheds that might be more subject to rain floods.

Bear Canyon Creek (17.0 square miles) is about 75 to 80% forested but, except near its mouth, it is accessible only on foot. The mainstream flows north and northwest, with elevations ranging from 5200 to nearly 8600 feet.

Logger Creek (2.48 square miles) is about 95 percent heavily forested with dense timber. The stream flows from southwest to northeast, with elevations ranging from 5500 to 8900 feet. Except for the mouth of the canyon, the watershed is extremely inaccessible except by switchback trail along one rim.

Pitcher Creek (2.33 square miles) is the most accessible of the four mountainous watersheds considered. With elevations from 4900 to 6400 feet, the basin is about two-thirds forested. The stream flows from northeast to southwest. A dirt road goes from the mouth of the watershed to a ranch house near the headwaters. The road is kept passable in the winter.

Squaw Creek (40.4 square miles) is fairly accessible by logging and forest roads. The stream flows mostly west and northwest, with elevations ranging from 5500 to 10,000 feet. Some of the area has been logged, and more logging is scheduled.

3. Berry Creek near Columbus.

This watershed, area 23.5 square miles, is relatively long and steep, running from north to south and southwest. Elevations range from 3650 to over 4500 feet. The basin is lightly timbered (10 to 15 percent) with scrub pines. There is no cultivation, and the area is used exclusively for grazing. There are no stock ponds. The soil is silty loam of low plasticity, with numerous rock outcroppings. The area can be traveled by a jeep or 4-wheel d drive vehicle.

The watershed was rejected because of its relative inaccessibility and lack of habitation.

4. Deep Creek near Kinsey (15 miles northeast of Miles City). This watershed, 10 to 12 square miles, is in a typical badlands region. It has been subject to flash floods producing large discharges which have caused damage to highway structures. The watershed was highly recommended by several organizations. It is an oval basin, with the main stream flowing from southeast to northwest into the Yellowstone River. Elevations vary from 2300 to 2800 feet. There are countless side canyons with steep slopes or vertical cliffs, and severe active erosion is evident over the entire basin. There is only short grass or prairie cover, with no trees or cultivation. The soil is sandy silt with some gravel, extremely erodible. Parts of the basin can be reached by jeep.

The basin would be an excellent site for badlands hydrology studies, and was rejected (reluctantly) because it is devoid of habitation, and there does not appear to be a practical means of determining rainfall measurements.

5. Dog Creek near Craig (5 miles north of Holter Dam). Dog Creek is in a wide, oval basin of 15.9 square miles area, running from west to east, discharging directly into the Missouri River. There are several side tributaries. The basin is moderately steep at the headwaters, but the valley downstream is uniform and has mild slopes. There are a few hay fields, but most of the basin is in native grasses. There is a small amount of scrub timber at higher elevations. The soil is mostly clay loam of low plasticity, and some active erosion is evident. The watershed is fairly accessible and there are some ranches.

This watershed was considered as an alternative to Lone Man Coulee at Valier. It would be fairly suitable, but it was rejected because it seems

to be in a less desirable hydrologic region, the spacing of ranches is not as good as at Lone Man Coulee, and stream ratings are said to be difficult here.

6. Wets Creek near Billings.

Wets Creek is a tributary of Pryor Creek southeast of Billings. It is 8.14 square miles in area ranging in elevation from 3400 to 3950. The main stream flows from west to east. Much of the watershed is on relatively flat table land which dips suddenly into steep draws and narrow valleys. Much of the top ridge land is cultivated in wheat, and there is considerable brush and trees along the streams. The rest of the basin is in prairie cover. The soil is a silty loam, with some plasticity (PI=17%). The watershed is easily accessible, with paved roads on two sides and a good gravel road on a third. There are several farms and ranches, particularly near the headwaters at the west rim. Most or all of the basin is on Crow Indian Reservation.

Wets Creek would be very suitable for the study, and was rated equal in qualification to Hump Creek at Reed Point. Wets Creek was rejected because it is farther from Bozeman.

IV. Watersheds Selected for Study

The four watersheds which were selected for the study, Bacon Creek (Antelope Creek Tributary#2), Duck Creek, Hump Creek, and Lone Man Coulee, are described below.

Bacon Creek (sometimes referred to in USGS reports as Antelope Creek Tributary #2) near Harlowton.

Description: Antelope Creek drains 88 square miles, rising in the Little Belt Mountains, and discharging into the Musselshell River at Harlowton. Bacon Creek (a tributary of Antelope Creek) does not extend clear to the mountains, but rises about 12 miles northwest of Harlowton, and joins Antelope Creek 1½ miles north of Harlowton. The basin of Bacon Creek is about 10 miles long and from 2 to 4 miles wide, with a total area of 21.2 square miles. The stream flows from northwest to southeast. Slopes are fairly mild and quite uniform, with elevations varying from 4200 to 4900 feet. The basin is bounded by relatively high bluffs and rock escarpments at a few isolated locations, but most of the boundary consists of gentle risesseparating the watershed from Antelope Creek on the northeast and from Hopley Creek on the southwest.

Land Use: There is very little cultivation on the watershed, and only scattered trees and a little brush, mostly along the streams. The entire area is used for livestock grazing, and is covered with short native grasses. There are, however a few small stock ponds. Mr. C. H. Robertson, near the mouth of the watershed, irrigates perhaps 40 acres. Springs apparently feed the stream and keep a small discharge flowing all the time.

Soils: The soils on the watershed are largely loams, and gravelly and silt loams, with numerous rocks. Gravels or shales underlie most of the area at 1 to 2 feet below the surface. The SCS hydrologic classification of the area is "B" (moderately erodible) except for steeper areas classified as "C" (above average erodibility).

Accessibility: An excellent gravel road from Harlowton follows the southwestern rim of the watershed for 3 or 4 miles, then crosses the watershed, and returns near the head of the basin. The old highway from Harlowton to Judith Gap and a branch line of the Milwaukee Railroad follow near the east side of the basin for about 5 miles. Most of the central portion of the basin, however, can be reached only by trail roads, and a jeep or 4-wheel-drive vehicle would be advisable.

Area Residents: Although there is evidence that several ranches were located on the watershed in the past, at the present time only two ranchers live on the basin. Mr. Harold J. Lode lives in Sec. 18, T9N, R15E, somewhat upstream from the center of the watershed. Mr. C. H. Robertson lives in Sec. 10, T8N, R15E, near the mouth of the watershed. The Nels Nelson ranch is located about $\frac{1}{2}$ mile west of the extreme upstream end of the basin, on Hopley Creek, in Sec. 9, T9N, R14E. Mr. Clyde Hiner lives in Sec. 7, T8N, R15E, about a mile west of the watershed. Mr. Robert Fulton lives in Sec 13, T9N, R15E, about 3 miles east of the watershed

Hydrologic: Antelope Creek has a history of occasional extreme discharges. On June 17, 1950, a flow of 24,400 cfs occurred (275 cfs per square mile on 88 square miles). Mrs. E. S. Bacon, whose husband ranched near the mouth of Bacon Creek, was drowned when their house was floated off its foundation. (The water stage recorder installed for this project is located 100 feet from the foundation of the Bacon house). On June 16, 1962, the U.S.G.S. reported a discharge of 3230 cfs on Bacon Creek. Surprisingly, Antelope Creek, two miles downstream reached a peak flow of only 1280 cfs on the same day. The 1962 flood represents 152 cfs per square mile on the Bacon Creek drainage.

Precipitation data gathered by the Weather Bureau near the Bacon Creek watershed include recording rain gage records at Martinsdale, 25 miles west, and non-recording raingage records at Barber, 25 miles southeast and at Judith Gap, 15 miles north. A non-recording raingage is now maintained at Harlowton, $1\frac{1}{2}$ miles south of the watershed, but the record from this station is less than ten years.

The Geological Survey has recording streamflow gages on the Musselshell River at Harlowton and Lebo Creek near Harlowton. In 1955 the USGS established creststage gages on Bacon Creek, on two other Antelope Creek tributaries, and on the main stem of Antelope Creek itself.

The Bacon Creek crest-stage gage is attached to a fence post in a small grove of trees a few hundred feet upstream from the confluence of Bacon Creek and Antelope Creek. The low water channel at this location is only 3 or 4 feet in width, but is contained within a broad flood plain of several hundred feet width. The crest stage gage is at too high a level to measure low channel discharges. Moderate discharges can be measured by wading, but higher discharges require slope-area measurement calculations.

Duck Creek near Brockway.

Description: Duck Creek drains 54.0 square miles in Prairie and McCone Counties, and discharges into the Redstone River about 4 miles southwest of Brockway. The basin is 13 or 14 miles long, and from 3 to 5 miles wide. Streamflow is from southeast to northwest. The basin is drained by two main streams, East Duck Creek and West Duck Creek, which lie parallel to each other, and which merge about 3 miles upstream from the confluence with the Redwater River. East Duck Creek drains about 1/4 of the watershed, the balance being drained by West Duck Creek. Elevations on the Duck Creek watershed vary from 2600 to 3625 feet.

The basin is mostly a rolling terrain, with the meandering streams formed in fairly broad, deep coulees. Toward the upstream end of the basin, the area is bad lands in character, with frequent bluffs and cliffs. There is relatively little evidence of active erosion over the watershed. There are only a few trees, along stream beds.

Land Use: About 1/4 to 1/3 of the basin is strip-farmed in wheat, while the remainder of the land is used for grazing. Two stock ponds were noted, both on the same short tributary east of East Duck Creek. There is no irrigation on the watershed.

Soils: There is some gravel in evidence on hilltops, but the soil is predominantly clay loam, with a fair amount of cohesion. Soil surveys of this area are not available, but it is believed that most of the watershed would be classified as "B" or "C" (moderate to above average erodibility).

Accessibility: The gravelled State Highway 253 from Terry to Brockway is routed between the east and west forks of Duck Creek for virtually the entire length of the watershed. This road, which is well maintained, provides ready access to the watershed, particularly in the vicinity of the east fork. A series of county roads, running south and west from Highway 253, provide access to the west fork. The condition of these latter roads varies from well gravelled to barely passable. A main east-west gravelled road provides access from Highway 253 to the mouth of the watershed.

Area Residents: Eight to ten ranchers live on or near Duck Creek Watershed. A partial listing includes:

William C. Jordan	Sec 15, T17N, R46E
Mrs. W. D. Dunlap	Sec 30, T17N, R47E
Frank Ueland	Sec 10, T16N, R47E
William Allen	Sec 5, T16N, R47E
Donald Hauk	Sec 21, T16N, R47E
Raymond Jonas	Sec 30, T16N, R48E
Jay Schwab	Sec 2, T15N, R47E

There are also ranchers in Sec 4, T16N, R47E and Sec 32, T16N, R48E.

Hydrologic: Precipitation data have been obtained by the Weather Bureau at several locations near the Duck Creek watershed. These include:

Brockway (non-recording) 5 mi NE of watershed
Terry 25 NW (recording) 5 mi E of watershed
Lindsay (non-recording) 30 mi E of watershed
Circle 7N (non-recording) 30 mi NE of watershed
Terry (non-recording) 30 mi SE of Watershed
Rock Springs (non-recording) 30 mi SW of watershed

The Rock Springs record dates back to 1915. The recording station at Terry 25 NW now has 25 years of data.

The Geological Survey maintains a recording station on the Redwater River at Circle. USGS crest stage gages were installed on East Fork Duck Creek in 1955 and on Duck Creek in 1957.

The presence of two crest stage gages is a unique feature, in that it permits independent study of the two forks of Duck Creek. The East Duck Creek area is 12.4 square miles above the crest stage gage. Both crest stage gages are attached to county bridges. The streams flow in well-defined channels at both locations. The East Fork channel is relatively free of vegetation (except for a few trees along its banks), but the bed of lower Duck Creek channel has a dense growth of watergrass, and is inclined to be boggy.

Duck Creek carried a peak discharge of 1000 cfs in March 1959, representing a yield of 18.5 cfs per square mile. At the same time East Fork Duck Creek, 12.4 miles in area, carried 273 cfs, or 22 cfs per square mile. A June 1963 storm produced a runoff of 52.4 cfs per square mile on East Fork Duck Creek, but only 16.5 cfs per square mile on the larger Duck Creek area. Hydrology texts often refer to a storm around 1920 on Spring Creek, about 8 miles north of Circle, as being one of the most intense rainstorms ever observed in the United States.

Hump Creek near Reed Point

Description: Hump Creek is the smallest (7.61 square miles) of the watersheds selected for study. A tributary of the Yellowstone River, it is located two miles west of Reed Point. It lies entirely within Sweet Grass County although its eastern boundary lies, at several points, within a few hundred feet of the Stillwater County Line.

Hump Creek flows mostly north, to enter the right bank of the Yellowstone. The basin is about 4½ miles long, and from 1 to 3 miles in width. Elevations range from 3770 feet at the mouth of the watershed, up to 4780 at the south end of the basin. The rim of the watershed is characterized by broad, flat, high-plateau-type terrain, but the ground drops sharply into numerous steep, narrow side-canyons which are tributary to the main stream. Some of the side tributaries are fed by perennial springs, but for most of its length the stream is dry except during spring snow melt, or following rainstorms. There is some scrubby pine, covering perhaps 15 to 20 percent of the entire watershed, and quite a lot of brush lining all the streams. An unusual feature is the Kent Lake, a small sink or pothole on the plateau adjacent to the south rim of the basin.

Land Use: The Hump Creek watershed is used almost exclusively for livestock grazing, and most of the basin is covered with native grass. A very small (about 5 percent) portion of the area is cultivated, mostly hay. These are one or two small stock ponds, on tributaries near the headwaters.

Soils: The predominant soil type apparently is a silty loam of low plasticity. There are, however, many rocky and gravelly areas on the surface, and rock outcroppings occur commonly.

The soils on the Hump Creek watershed are classified as a C-5 mixture of Alluvial, Chestnut and Lithosol. These are generally thin to moderately thick soils, stony, and underlain with clay or rock. The SCS hydrologic grouping would probably be B to C.

Accessibility: The watershed is quite accessible, except in very wet weather. A county road from Reed Point to Absarokee follows the west rim of the watershed. This road, which is maintained as a Star Route mail route is gravelled, and is usually passable. The east rim of the basin is reached via a county road from Reed Point to Columbus. This road, however, is steep with switchbacks as it climbs from the valley floor to the rim, and is not as well maintained as the west rim road. Ranches in the center of the watershed are reached by a road along Hump Creek itself. This road, which terminates at the Krone and Mysse ranches near the center of the watershed, would be impassable following major storms.

Area Residents: Much of the land on Hump Creek watershed is owned by ranchers who live on adjoining watersheds. There are, however, 3 or 4 ranches that are suitably located for hydrologic measurement purposes. The Thorval Krone and Carl Mysse ranches are situated side by side at almost the exact center of the basin. Both ranch headquarters are located on Hump Creek itself, in the bottom of the canyon. The Glenn Cain Ranch on the plateau south of the basin is actually about 1/2 mile off the watershed, separated from the watershed proper by Kent Lake, The Cain family lives in Billings, but spend holidays and vacations on the ranch. Their ranch foreman lives on the ranch all the time. A fourth ranch owned by David Kenfield, is located on the rim, near the southeast corner of the basin. The north end of the watershed does not have any residents.

Hydrologic: The Weather Bureau has operated a recording raingage in Reed Point, 2 miles east of the mouth of the watershed since 1939. A second recording gage is located at Malt, 35 miles northeast of Reed Point. Long term non-recording rain gage records are available from Rapelje and Big Timber, with shorter term records available from Columbus and Fishtail.

The Geological Survey has recording stream flow records from the Yellowstone River at Big Timber, and from the Stillwater River and Rosebud Creek near Absarokee. The crest-stage gage installation, which was made in May 1959, is one of four gages in the close vicinity. The other watersheds so instrumented are Work Creek, Berry Creek and Allen Creek.

The crest stage gage on Hump Creek is attached to the concrete bridge on U. S. Highway 10. Present information is that Interstate Highway 90 construction will not disturb this bridge. The bridge location is 100 feet south of the Northern Pacific railway bridge, and 1000 feet south of the creek's confluence with the Yellowstone River. The stream at this location is in a well-defined, tree-lined channel. No significant discharge peaks have occurred at Hump Creek since the crest stage gage installation.

Lone Man Coulee near Valier.

Description: Lone Man Coulee watershed, in Pondera County, is a 14.1 square mile basin located five miles south of Valier, and about two miles south of Lake Frances. This is a long narrow basin (about six miles by 2½ miles) sloping from west to east. Elevation varies from 3750 feet to 4150 feet. The basin is drained by two main streams which join near the mouth of the watershed. Miller Coulee flows mostly east, and drains about 2 square miles of the northern portion of the watershed. Lone Man Coulee flows east and northeast, and drains the balance of the watershed. Lone Man Coulee discharges into Heines Creek 2½ miles downstream from the confluence of Miller and Lone Man, and Heines Creek empties into the Dry Fork of the Marias River. The portion of the Lone Man watershed downstream from the Lone Man-Miller confluence was not considered for this study.

The Lone Man watershed is in an area of rolling hills, with rock outcrops over some of the steeper hills. Most of the hillsides, however, have fairly light slopes.

Land Use: About 75 percent of the watershed is cultivated, strip-wheat farming exclusively. The steeper slopes are in native grass. There are 2 or 3 small stock ponds, all on Miller Coulee near the north edge of the basin.

Soils: Soil types on the basin are generalized as follows:

50% - Morton Loam - well-draining, high water-holding capacity loam with lots of lime, over sandstones and shales.

25% - Fairfield Loam - loam over gravelly loam, 9 to 14 inches deep over 3 to 4 feet of silty clay.

25% - Scobey Loam - sandy and silty loams with boulders on surface, over glacial drift.

Small amounts of Bainville Loam on sharply rolling surfaces.

The SCS Hydrologic classification for these soils is B.

Accessibility: There are two main north-south county roads across the basin. These roads are well-gravelled and generally passable. Two other north-south roads are passable for part of the distance across the basin, or during good weather only. There are two main east-west roads, one just north of the basin, and one near the south rim. A third road up the middle of the basin is maintained for part of the distance only. The northernmost of the three east-west roads is usually passable, but the other two are not usable in wet weather.

Area Residents: At least six ranches are located on the watershed, with 2 or 3 others close to the watershed boundary. The ranches are well dispersed, and hardly any spot on the watershed is more than a mile from a

habitation.

A partial listing of area residents includes:

John Toren	Sec 34, T29N, R5W
James Geiger	Sec 26, T29N, R6W
Elwin Gossard	Sec 3, T28N, R6W
Harry VandenBos	Sec 33, T29N, R5W
C. W. Fields	Sec 3, T28N, R6W

Hydrologic: Recording rain gage records are maintained by the Weather Bureau at Dupuyer (6 miles west) and Choteau (30 miles south). Non-recording stations are well scattered, and include Valier (5 miles north), Conrad (15 miles southeast), Shelby (28 miles northeast), Pendroy (10 miles south), and Bynum (22 miles south).

The Geological Survey has maintained crest-stage gages at Lone Man Coulee (and also at Heines Coulee and North Fork of Dry Fork Marias River) since May 1959. The nearest USGS recording stream gaging station is on the Marias River at Shelby.

The crest-stage gage on Lone Man Coulee is at a county road culvert crossing (72-inch diameter) a few hundred feet downstream from the confluence of Miller and Lone Man Coulee.

A major flood occurred on Lone Man Coulee on June 16-18, 1948, when a flow of 1820 cfs occurred from 11.4 square miles (160 cfs per square mile). After the crest-stage gage installation in 1959, the peak discharge was 32 cfs prior to the flood of June 7-8, 1964. That storm produced 1764 cfs from 14.1 square miles (125 cfs per square mile). (The June 1964 flood was described in a special progress report prepared under this project).

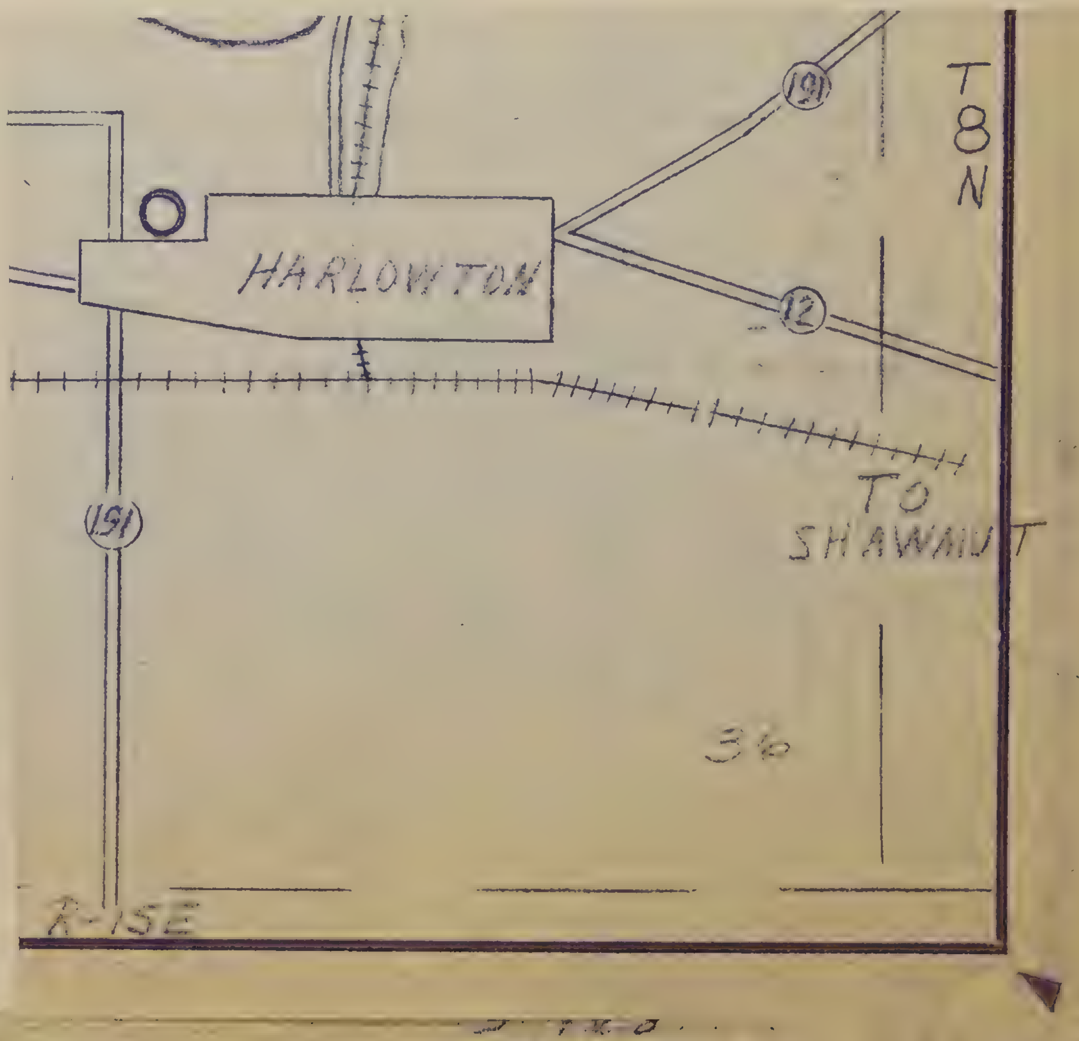
V. Conclusion

The foregoing report has presented information regarding method of selection of watersheds, and descriptions of watersheds considered but rejected, as well as descriptions of the watersheds chosen for hydrologic study. More comprehensive studies of soil types, land use, and other hydrologic characteristics are in progress. This report was intended to provide background and general information.

APPENDIX

A. MAPS OF SELECTED WATERSHEDS

B. AERIAL PHOTOGRAPHS OF SELECTED WATERSHEDS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TO SHAWMUT
T8N
R-15E
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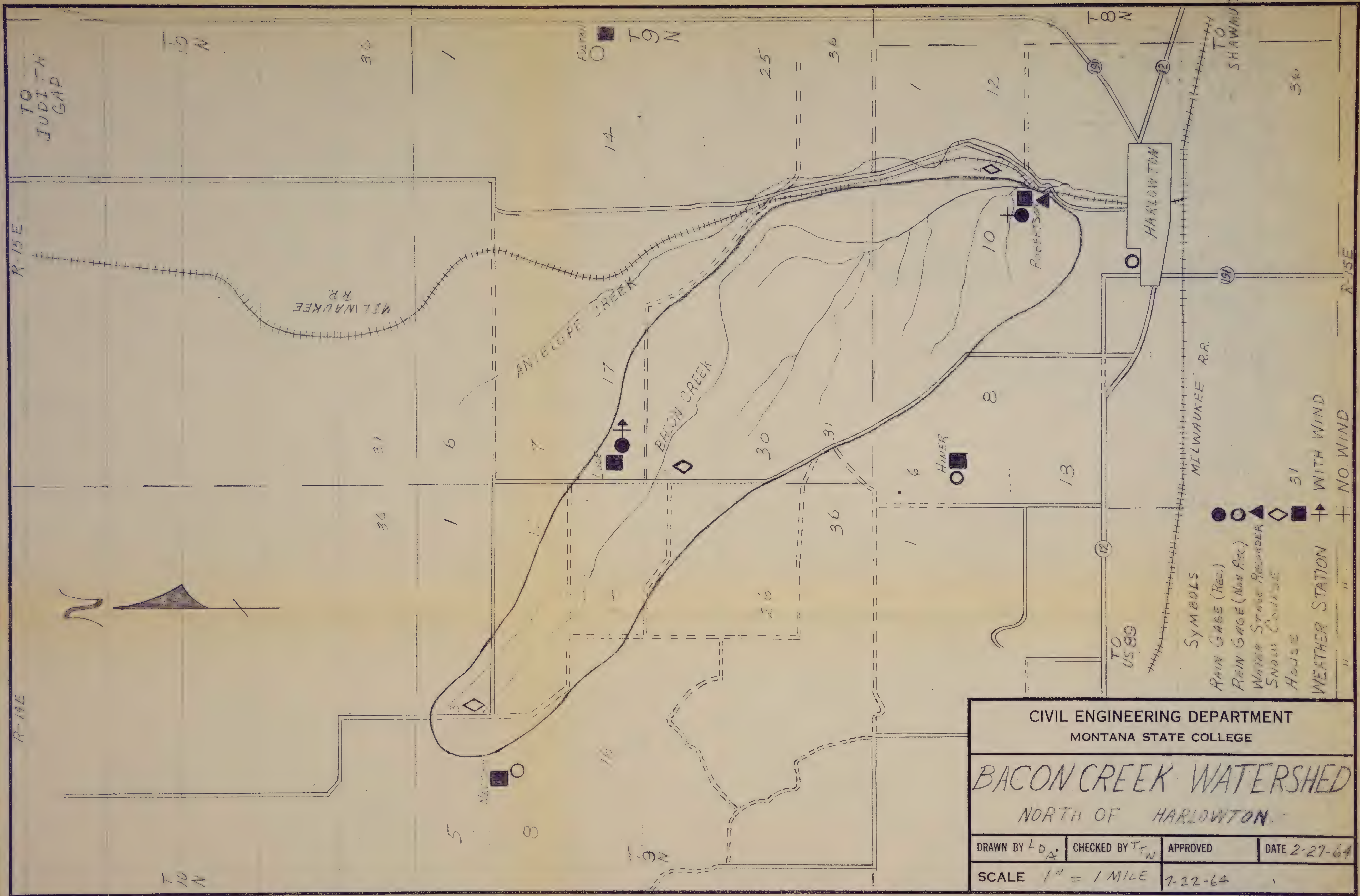


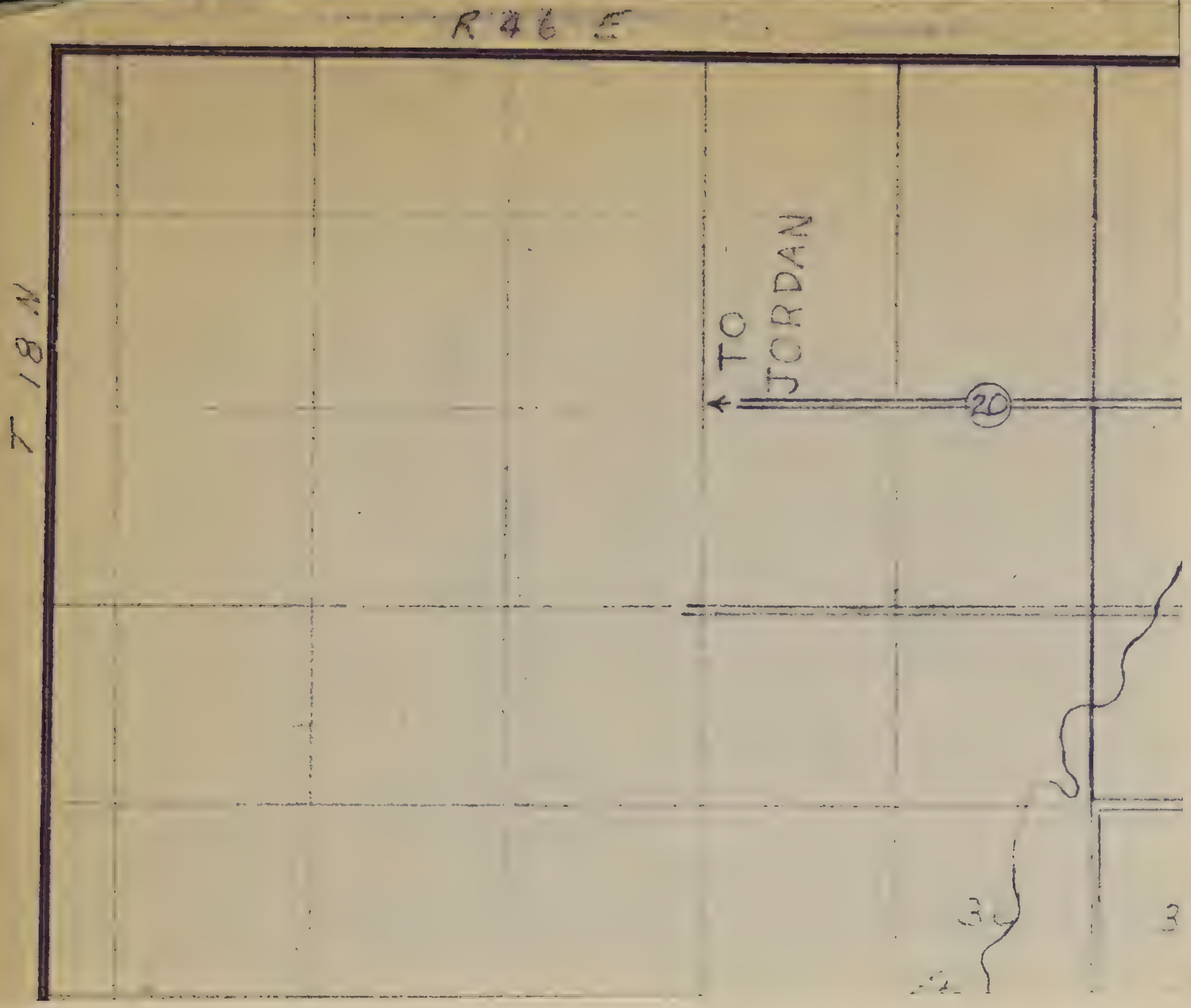
CIVIL ENGINEERING DEPARTMENT
MONTANA STATE COLLEGE

BACON CREEK WATERSHED

NORTH OF HARLOWTON

DRAWN BY L D A.	CHECKED BY T T W	APPROVED	DATE 2-27-64
SCALE 1" = 1 MILE		7-22-64	

EUGENE DIETZGEN CO.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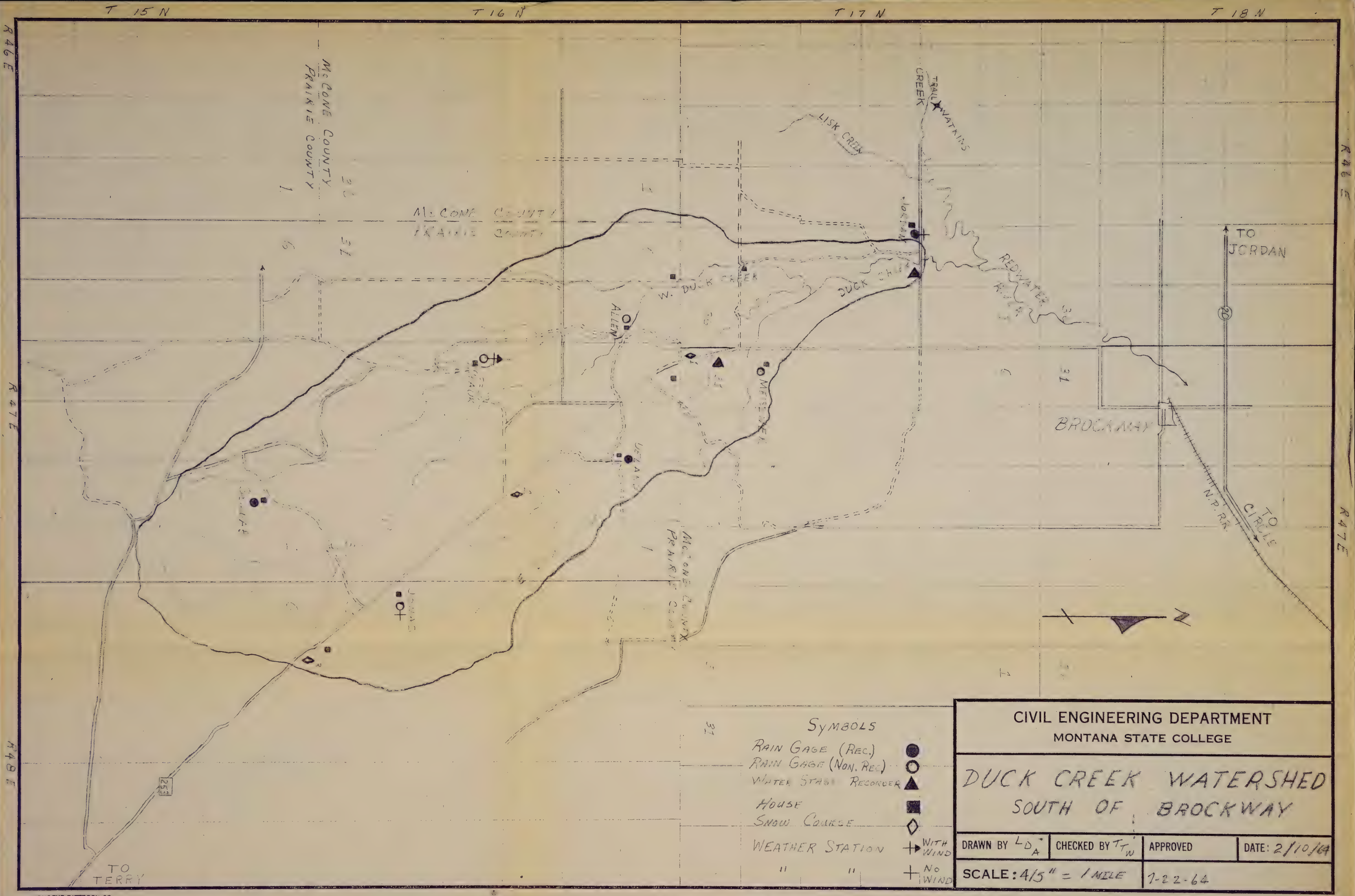
T 18 N
TO JORDAN
20
3
3



Symbols

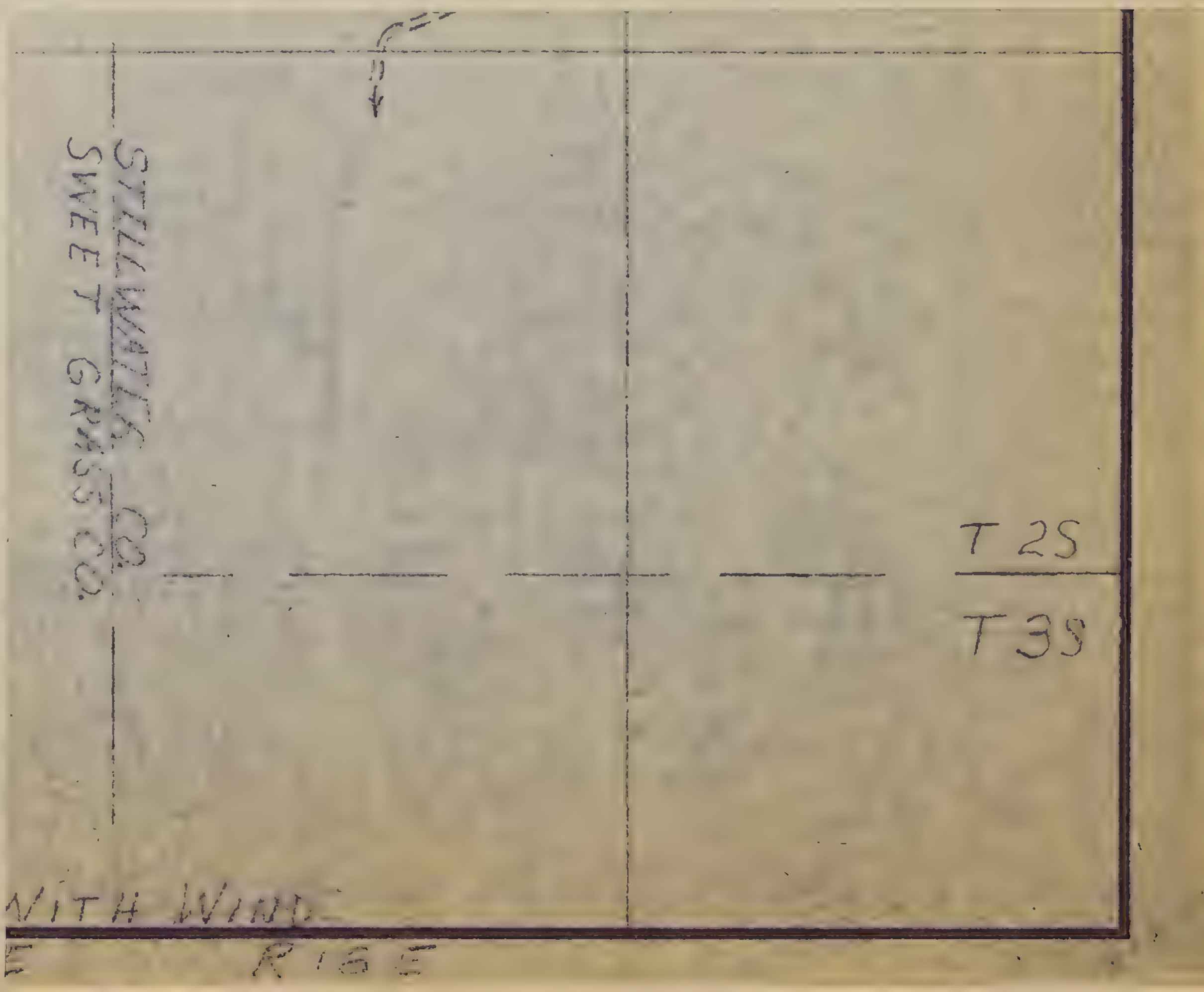
Rain Gage (Rec.) ●
Rain Gage (Non. Rec.) ○
Water Stage Recorder ▲
House ■
Snow Course ◇
Weather Station ✛ With Wind
" " + No Wind

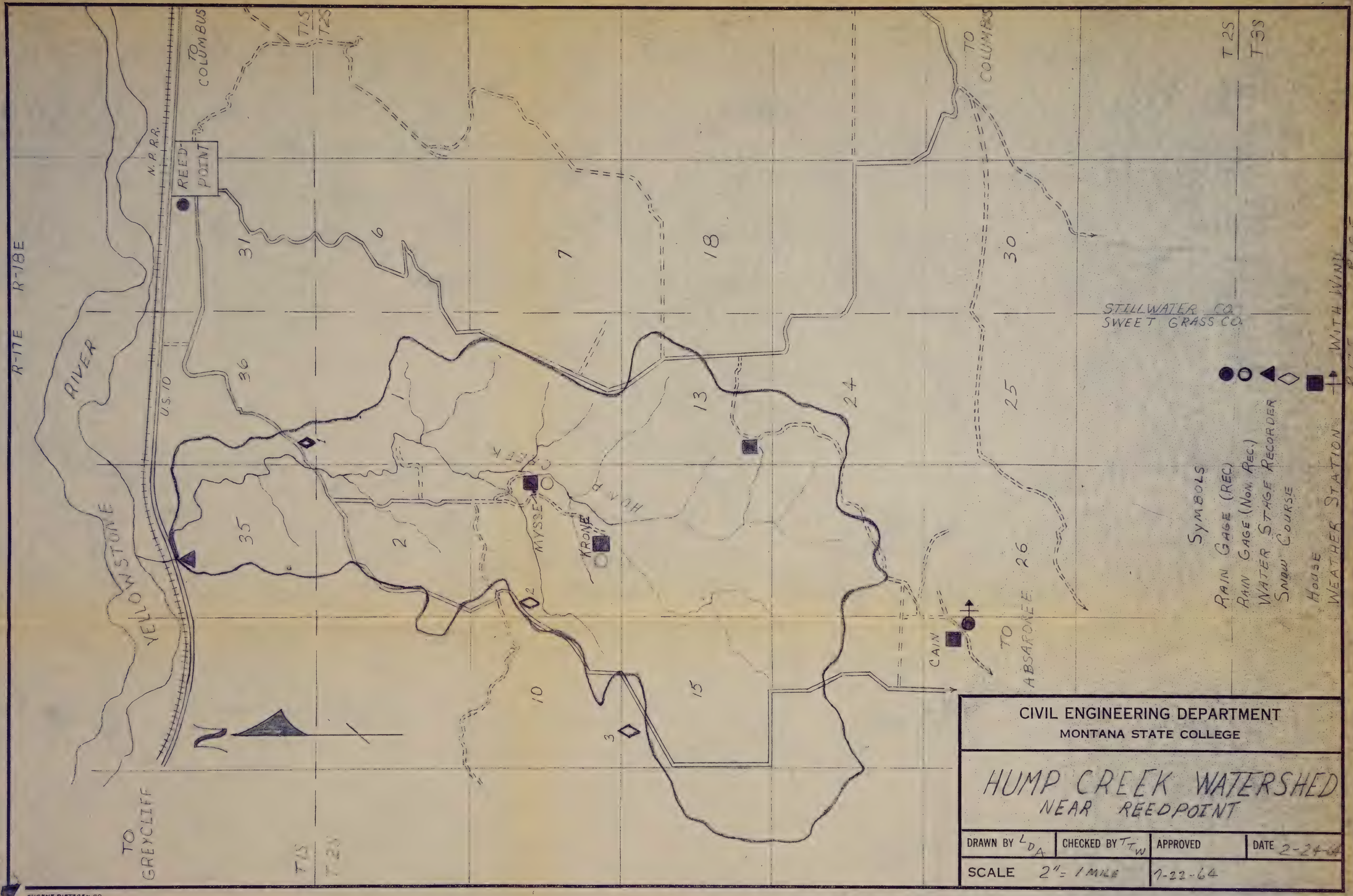
CIVIL ENGINEERING DEPARTMENT
MONTANA STATE COLLEGE

DUCK CREEK WATERSHED
SOUTH OF BROCKWAY

DRAWN BY LDA	CHECKED BY TTW	APPROVED	DATE: 2/10/64
SCALE: 4/5" = 1 MILE	1-22-64		

EUGENE DIETZGEN CO.


STILLWATER CO.
SWEET GRASS CO.
T 2S
T 3S
WITH WIND
R 16 E

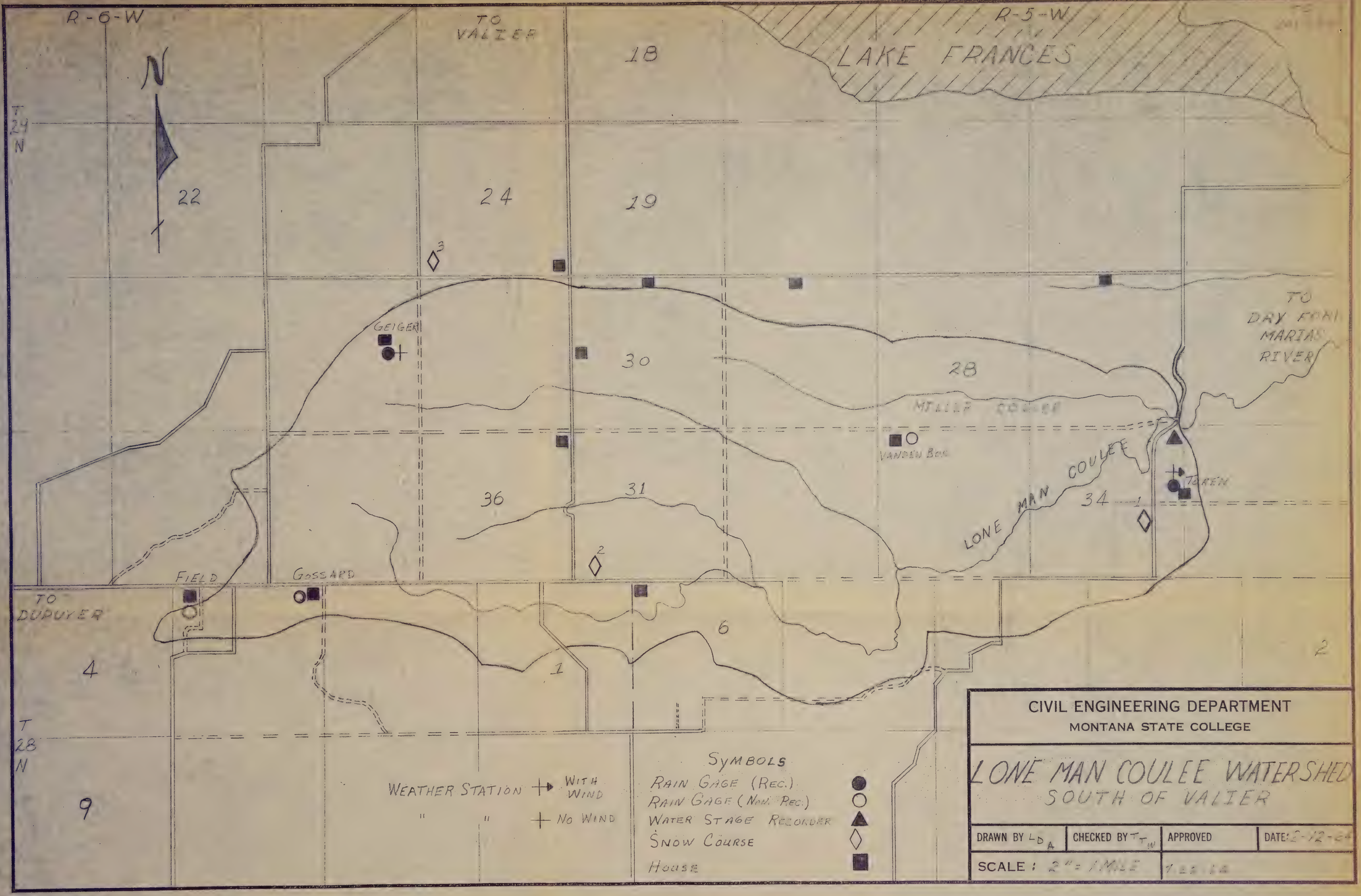


CIVIL ENGINEERING DEPARTMENT
MONTANA STATE COLLEGE

HUMP CREEK WATERSHED
NEAR REEDPOINT

DRAWN BY LDA | CHECKED BY TTW | APPROVED | DATE 2-24-64
SCALE 2" = 1 MILE | 1-22-64

70



CIVIL ENGINEERING DEPARTMENT
MONTANA STATE COLLEGE

LONE MAN COULEE WATERSHED
SOUTH OF VALIER

DRAWN BY L D A	CHECKED BY T T W	APPROVED	DATE: 2-12-64
SCALE : 2" = 1 MILE		1:22:64	

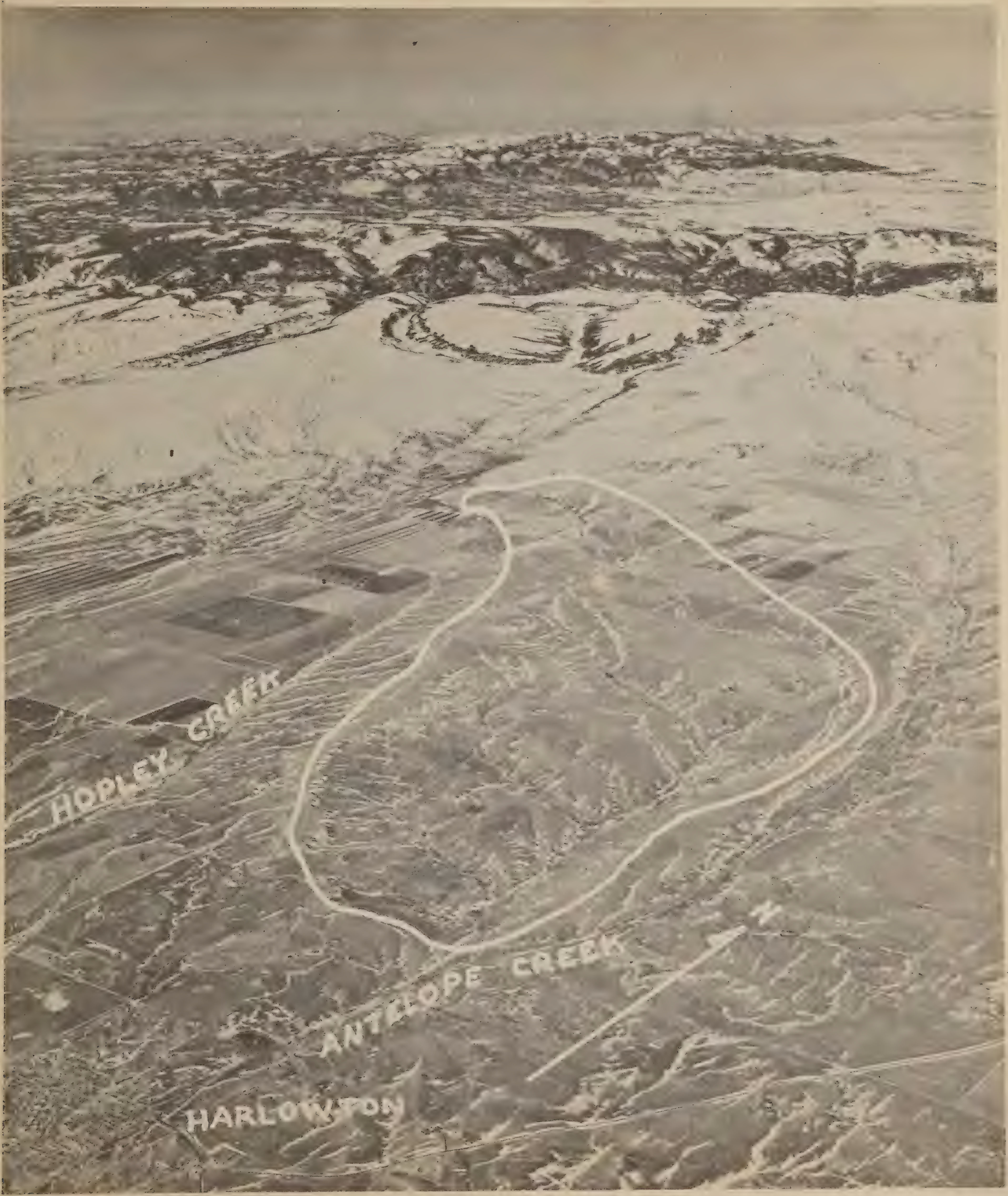


FIGURE 1 - Bacon Creek, looking northwest

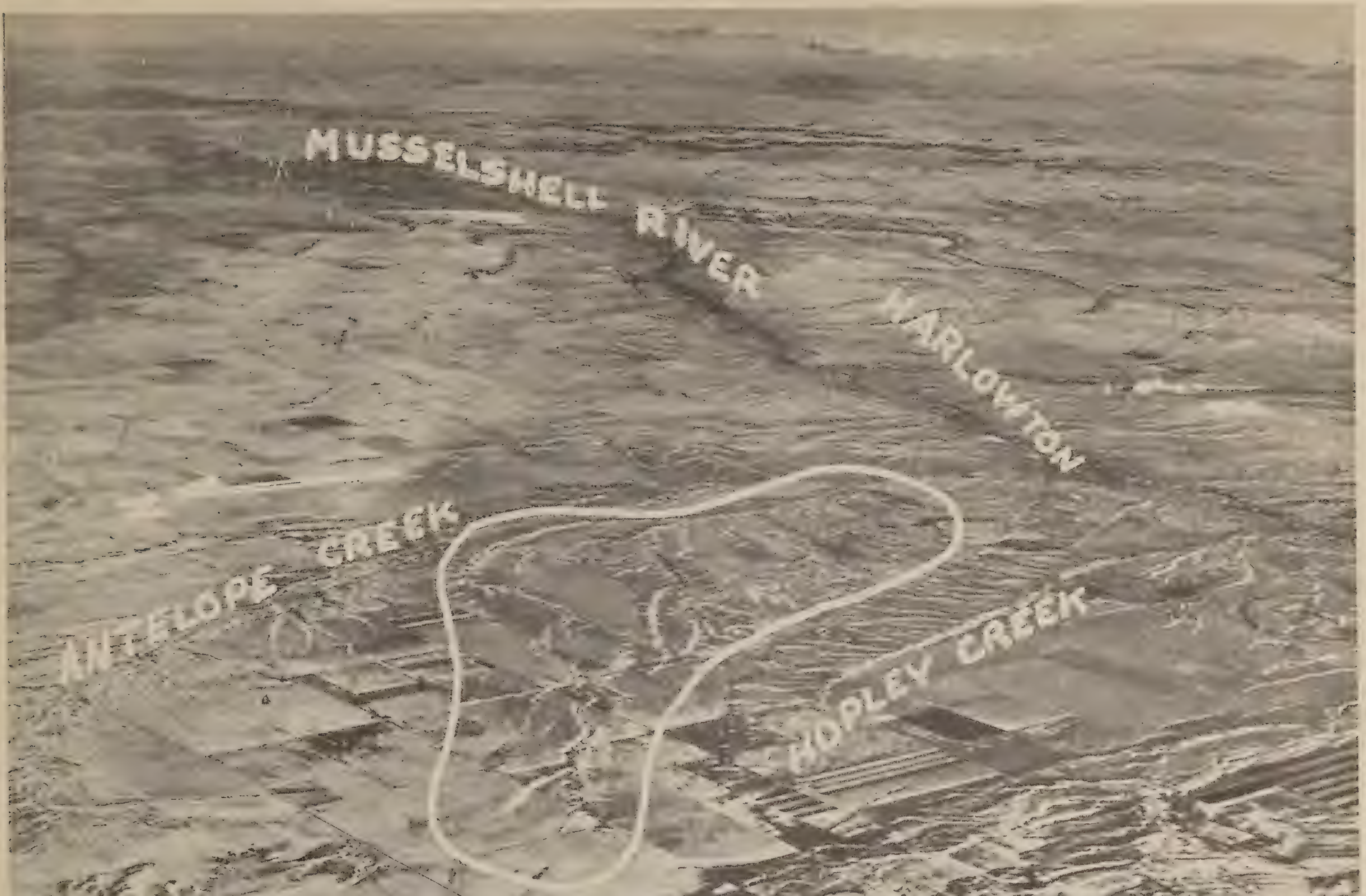


FIGURE 2 - Bacon Creek, looking southeast

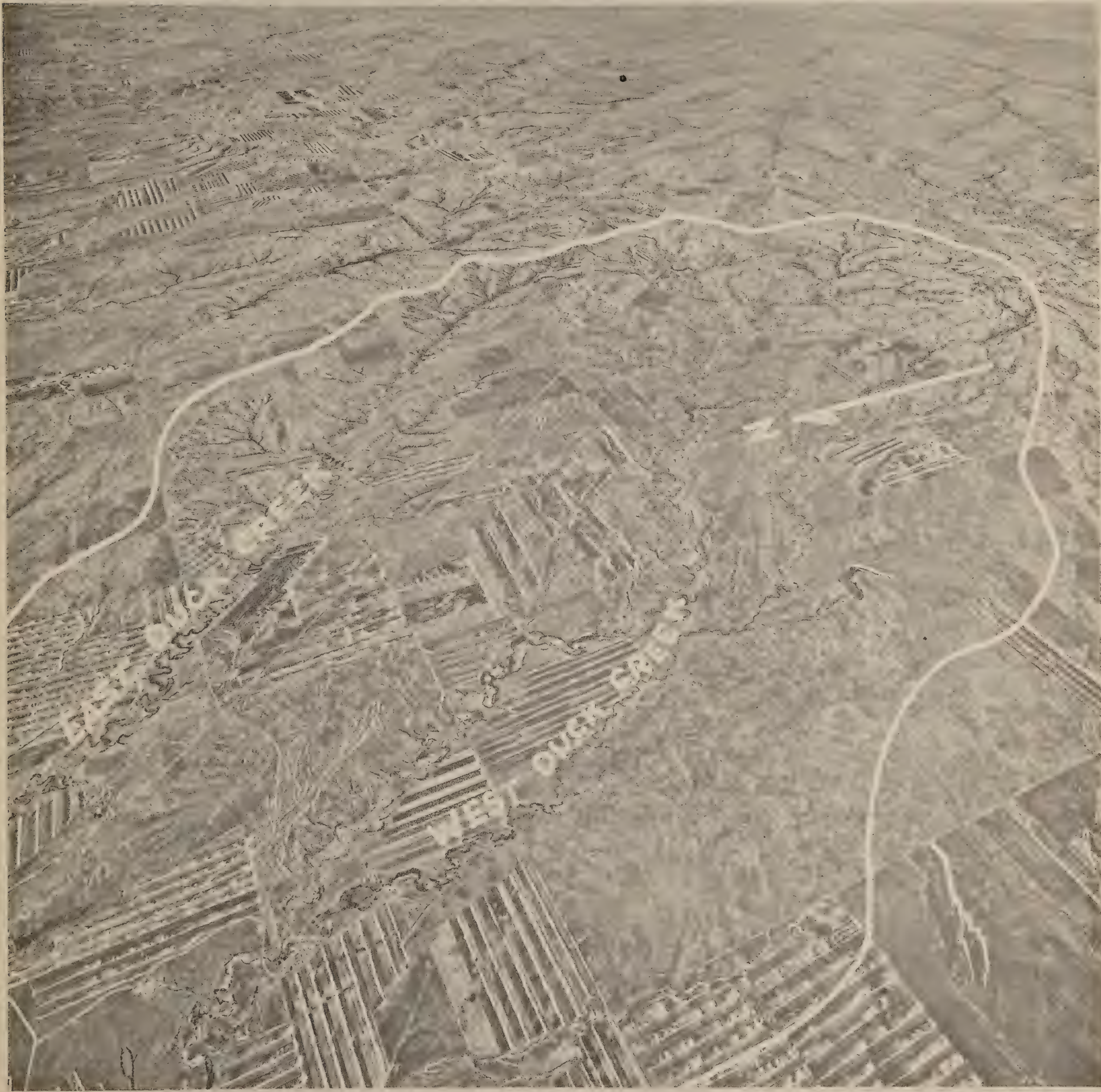


FIGURE 3 - Duck Creek, looking southeast

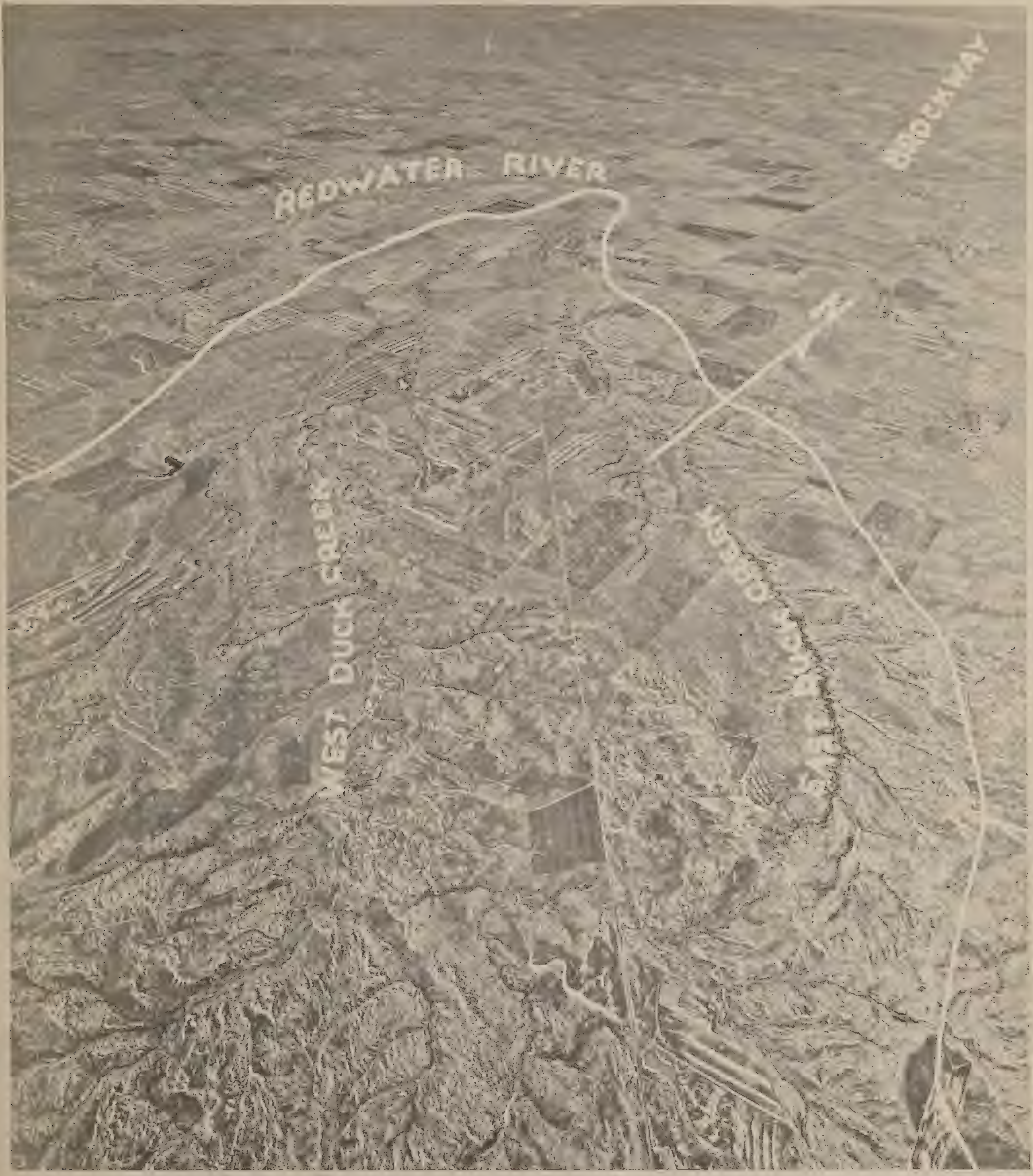


FIGURE 4 - Duck Creek, looking northwest

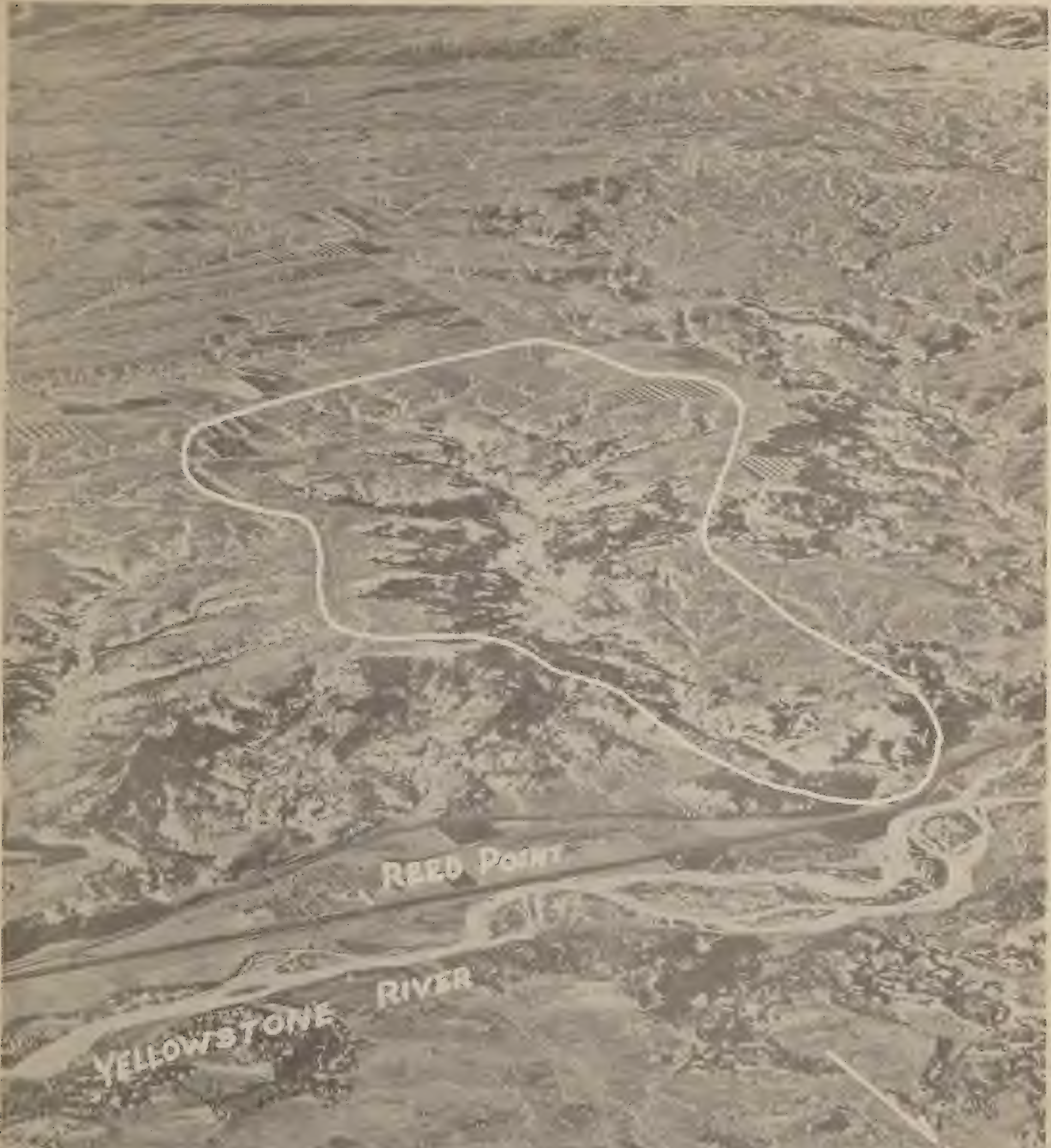


FIGURE 5 - Hump Creek, looking southwest

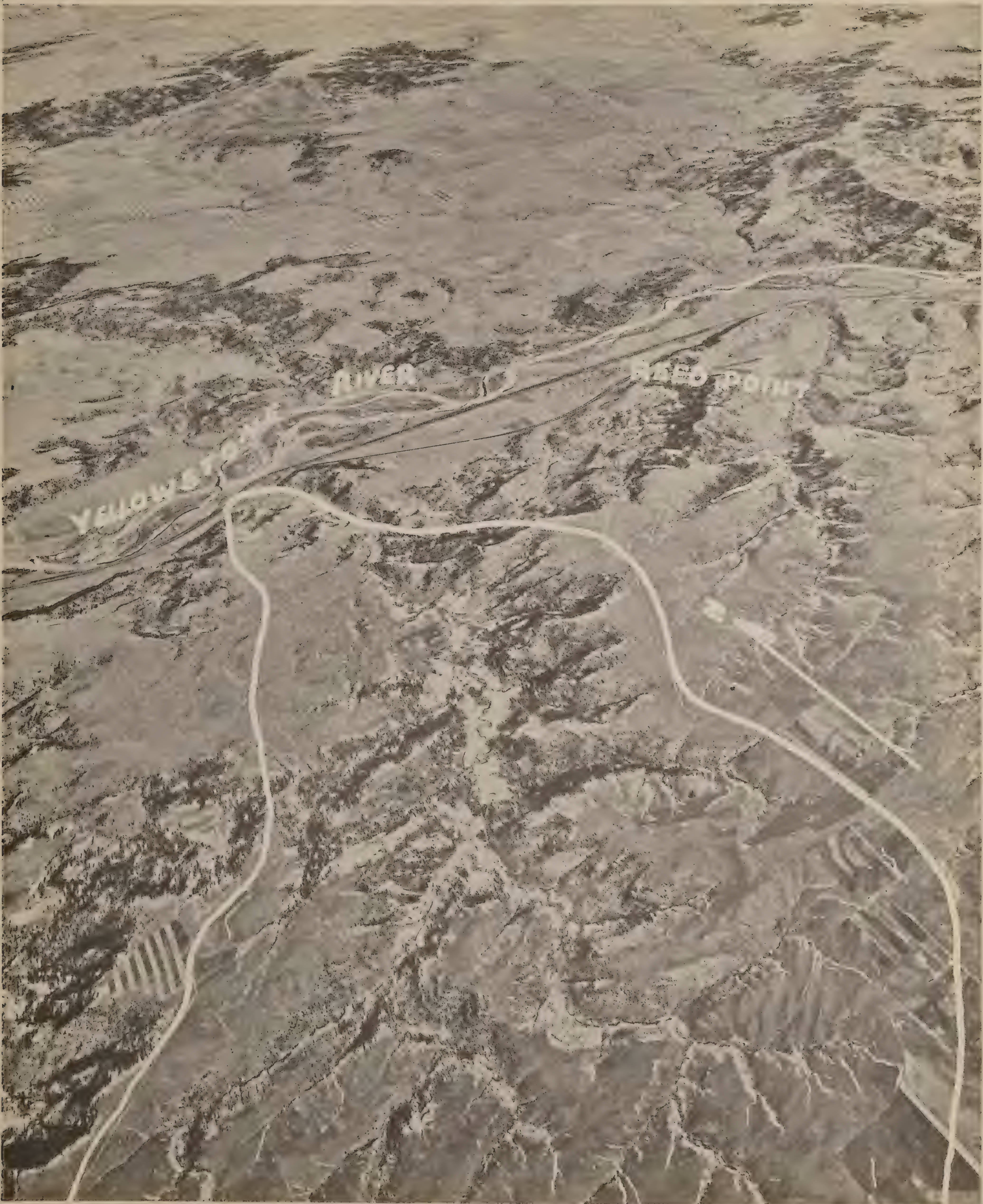


FIGURE 6 - Hump Creek, looking northeast

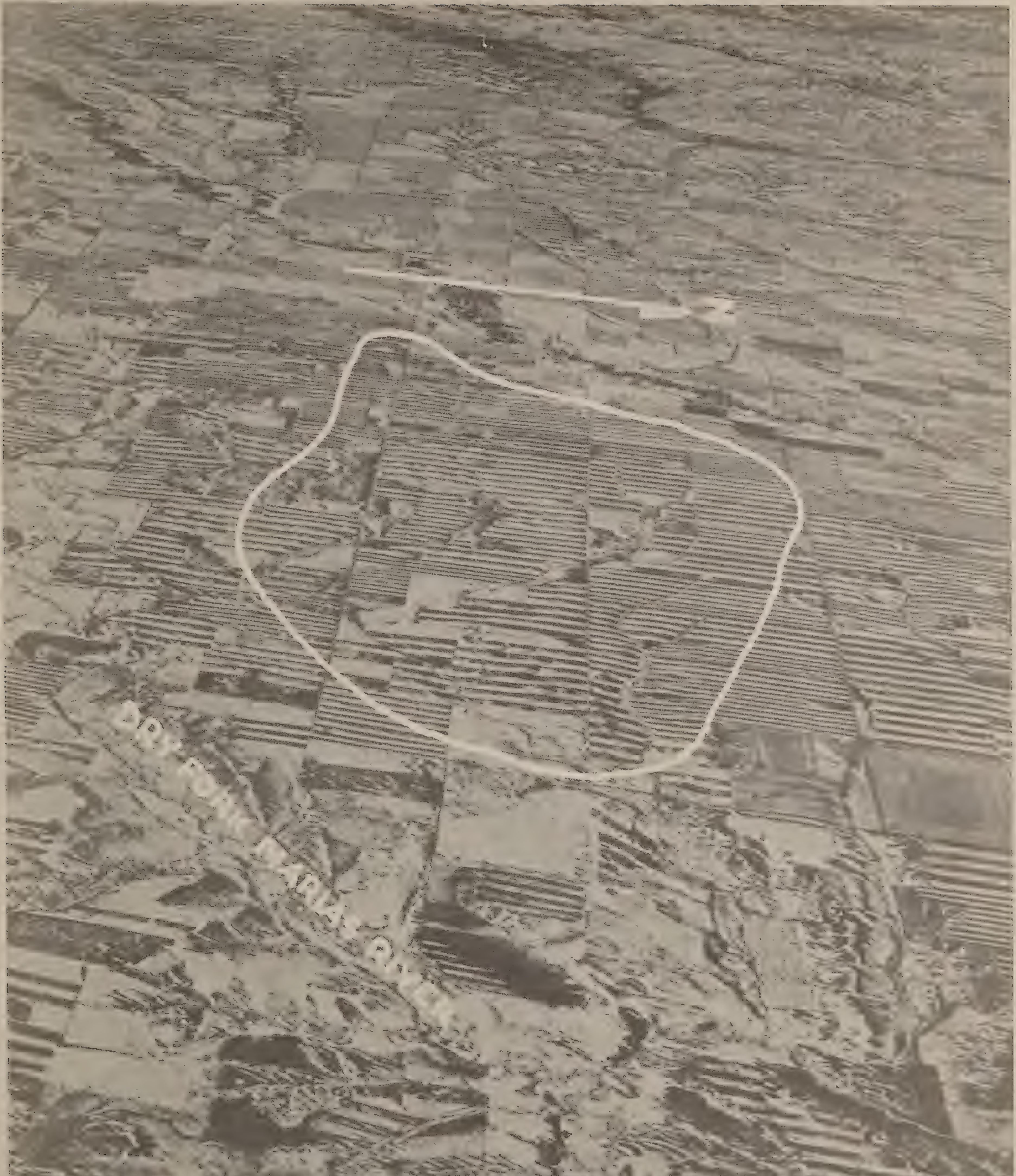


FIGURE 7 - Lone Man Coulee, looking west

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ABSTRACT

Predicting Frequency and Magnitude of Peak Flows from Drainage Areas of 1 to 100 square Miles in Montana

There is at present a shortage of reliable information regarding flood frequencies and peak discharges from small drainage areas in Montana. Information of this nature is of great importance to the designer of drainage structures. The U. S. Geological Survey is currently conducting in cooperation with the Montana State Highway Commission, a "Small-Area Peak-Flow Highway program" to determine peak flow rates at selected stations on small watersheds in Montana. Seven to ten years record at 161 crest-stage gaging stations is contemplated. The Geological Survey project does not provide for analysis of precipitation and other climatological data, nor for extensive hydrologic investigations of the watersheds.

A three-phase research investigation is proposed herein:

1. Precipitation data gathered by the U. S. Weather Bureau (and other sources) will be assembled and studied to determine what correlation exists between such data and peak flows on small watersheds. It is hoped that on some watersheds peak flows might be predicted directly from precipitation data at certain Weather Bureau stations.

2. Comprehensive hydrologic studies of three of the U. S. Geological Survey watersheds will be made. Data obtained will be correlated with the results of the Geological Survey program. It is believed this study will extend the usefulness of that program, and will aid in determining what length of record of peak flows is necessary to safely predict floods of given frequencies.

3. A preliminary study of the hydrology of snow melt floods will be made to determine to what extent such floods are significant for design of drainage structures. If this analysis indicates the need of additional field data, a separate proposal for the gathering of such data will be submitted.

The first and third phases of the research proposed herein involve the utilization of data already available or which are being obtained by other persons. In the second phase, new data will be gathered specifically for this project.

RESEARCH PROSPECTUS

I. TITLE

Predicting frequency and Magnitude of Peak Flows from Drainage Areas of 1 to 100 sq. miles in Montana

II. DESCRIPTION OF PROPOSED RESEARCH

A. Statement of Problem

An important problem in highway design is that of determining design flow capacities for drainage structures. Although the problem exists for structures of all sizes, there is a particular shortage of design criteria for small structures such as culverts. Culvert installations ordinarily are used where the discharge originates from small watersheds of a few acres or a few square miles, and these small watersheds are subjected to high-intensity small-area storms which may cause high rates of discharge per square mile of drainage. The determination of the frequency of rates of discharge of various magnitudes is essential to economic engineering design. These discharges may be caused by rain, snow-melt, or a combination of rain and snow-melt.

B. Need for and Objectives of Proposed Research

Until the year 1955 there was very little reliable information available regarding flood frequencies and peak discharges from small drainage areas in Montana. In that year the U. S. Geological Survey instituted a Small-Area Peak-Flow Highway program in cooperation with the Montana State Highway Commission. This program involves the determination of peak flow rates at selected stations on small watersheds in Montana. Measurements were begun at 45 creststage gaging

stations in 1955, and more stations were added in 1959. As of 1 October 1962, data were being gathered at 161 stations. Present plans call for termination of the project following the 1964 water year, at which time there will be 7 years of data from the majority of the stations and 10 years of record from the remainder. The final report will provide annual peak values of discharge which have occurred at each station.

In order that the maximum possible utility and benefit may be realized from the Geological Survey program, it is proposed that an intensive study of the hydrology of a few of the watersheds included in that project be made. Hydrologic characteristics of the drainage areas, as well as data on rainfall duration-depth frequencies should be examined in detail. The U. S. Geological Survey data would provide valuable criteria for checking flood flows predicted from the proposed investigation. It is believed that the study proposed will extend the usefulness of the Geological Survey program, and will yield valuable information to the highway engineer faced with specific design problems.

The objective of the study proposed herein will be to obtain information which will at least partially answer the following questions:

1. Can existing precipitation and climatological data be used to predict the frequency of flood magnitudes on small watersheds in Montana.

2. Do comprehensive studies of a few of the watersheds in the peak-flow study of the U. S. Geological Survey (i.e., detailed precipitation measurements, soil types, topography, land use, continuous-flow measurements, etc.) yield data which extend the usefulness of the results obtained from the peak flow determinations being made by the Geological Survey?

3. To what extent do snow-melt floods produce important peak flows from small watersheds? If they are important, what hydrologic and/or meteorological data are required for their prediction?

4. What frequency of flood can be safely predicted from 7 to 10 years of peak-flow records? What length of record should be made by the Geological Survey to safely predict floods of given frequencies?

5. What limitations should be imposed on the extrapolation of flood frequency predictions from one watershed to another?

C. Research Methods and Procedures

The research investigation which is proposed herein is divided into three phases, with the investigation to proceed on all three phases concurrently. The first phase involves the collection and analysis of precipitation data; the second, an intensive field study of three small watersheds in Montana; and the third, an investigation of snow-melt flood peaks. In the first and third phases, data which are already available or which are being obtained by other persons will be utilized. In the second phase, new data will be gathered specifically for this project. A description of each of the three phases of the investigation follows:

1. Collection and Analysis of Precipitation Data:

Precipitation data gathered by the U. S. Weather Bureau (and other sources) will be analyzed and studied to determine rainfall duration-depth-frequency relations for such sub-areas of Montana as is feasible. It is recognized that high intensity storms covering small areas may produce unusual discharges on individual watersheds, even though such storms may not produce excessive precipitation at established precipitation stations. It is hoped that some auxiliary precipitation data is being gathered by individuals who

live in the vicinity of the Geological Survey study areas, and that such data, although not complete or extremely precise, would provide valuable information to supplement the Weather Bureau data. An attempt will be made to obtain as much auxiliary data of this sort as possible.

All the obtainable precipitation data will be compared with the Geological Survey streamflow records to determine what correlation exists between the precipitation data and peak flows on small watersheds. Although it is recognized that many factors other than precipitation (i.e., drainage network, soil types, soil moisture conditions, etc.) influence peak flows, it is hoped that on some drainage areas precipitation data at certain Weather Bureau stations might be utilized directly to predict peak flows for these watersheds.

2. Field Study of Small Watersheds: It is proposed to select three of the Geological Survey watersheds for intensive study. These watersheds will be located at three widely separated locations, and will be selected in areas that appear to be particularly troublesome, or that are located at large distances from existing precipitation stations. However, the locations will be finally determined by the availability of reliable persons willing to assist with the study. Perhaps some Highway Department personnel might be utilized for this purpose.

Detailed surveys will be made at each of the three selected locations, to determine areal extent, slopes, topography, soil types, cover, and other drainage characteristics. Each of the watersheds will be equipped with recording rain gagos, and with one or more non-recording rain gages, as deemed advisable. Each watershed will be equipped with a reliable measuring device for obtaining continuous records of runoff. Flood hydrographs together with rainfall data will provide data for unit-hydrograph analysis.

The detailed studies of the three selected watersheds will provide data from which rather thorough hydrologic analyses may be made. Such analyses will include the unit hydrograph method including attempts to synthesize unit hydrographs for non-gaged areas.

3. Investigation of Snow-Melt Flood Peaks: A preliminary study of the hydrology of snow-melt flood peaks will be made. This study will include analysis of such data as are available relating to the snow-melt flood problem on small watersheds. If this analysis indicates the need for additional field data, a separate proposal for the gathering of such data will be submitted for consideration in time to include the gathering of such field data concurrently with the field work associated with phase two of this investigation.

III. SCHEDULE

A. Proposed Starting Date: 1 July 1963.

It is desirable to select the three watersheds to be studied in detail, and to install instrumentation before the main portion of the 1964 runoff season begins. Analysis of data already available will be started as soon as possible after the starting date for the project.

B. Proposed Completion Date: 30 June 1967.

Field data to be obtained in phase two will be gathered until the end of the 1965 water year (30 September 1966) and these data, together with those gathered by the Geological Survey, Weather Bureau and other sources, will be analyzed prior to preparation of the final report.

IV. FACILITIES AVAILABLE

An IBM 1620 electronic computer is available on the Montana State College campus; it will be used in the reduction of data, and in the performance of statistical analyses.

V. PERSONNEL AVAILABLE

A. Organization

1. Supervisor:

a) Theodore T. Williams, Assistant Professor of Civil Engineering and Mechanics, Montana State College. B. S. Colorado State University, 1949; M. S. 1956. Principal area of interest: Applied Hydraulics and Irrigation Engineering.

b) Alfred C. Scheer, Associate Professor of Civil Engineering and Mechanics. B. S. Iowa State College 1948, M. S. 1950. Principal areas of interest: Soil Mechanics and Highway Engineering.

Note: One of the above persons will be designated Principal Investigator upon approval of the project.

2. Assistants:

a) Data Collection: one graduate student plus Highway Department personnel

b) Data Analysis: two graduate students

B. Other Staff

Dr. E. R. Dodge, Head of the Department of Civil Engineering and Mechanics, Montana State College.

TITLE: Peak Flow Project

DETAILED BUDGET FOR FISCAL YEAR 1963-64

START: 7/1/63

STAFF: Summer '63			
Investigators 1-3 mos.			
(Williams or Scheer)	$2250		
Addit. Staff (1/4 time - 3 mos.)			
Dodge	600		
10/1 - 6/30			
Prin. Investigator (1/4 time - 9 mos)	1700		
Graduate Student (1) - 9 mos.	1800		
	$6350		
Retirement and Ins. (8%)	500		
Sub total		$6850	
Field Work, wages			
1 full time Student Assist. - 3 mos.			
clerical	1300		
Supplies	500		
Travel	1500		
Sub total		3300	
Total Direct		10,150	
Indirect Costs (30%)		3,050	
			$13,200
Equipment - Precip. gages, Flow Recorders, etc. incl. installation			5,500
TOTAL FOR 1963-64			$18,700

Note: Indirect Costs include estimated actual costs for college-owned equipment use, operation and maintenance, library, administration, water, light, heat, graduate student services, and proportionate vacation pay. Actual indirect costs subject to audit in accord with Bureau of Budget Circular A21.

ESTIMATED TOTAL PROJECT BUDGET
Project Duration - July 1963 through June 1967 $53,700

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DRAINAGE CORRELATION RESEARCH PROJECT

Interim Report #2

PRECIPITATION AND STREAMFLOW INSTRUMENTATION FOR SMALL WATERSHEDS

by T.T. Williams

I. Introduction

The Drainage Correlation Research Project is an investigation of peak discharges from small watersheds in Montana. Conducted by the Department of Civil Engineering and Engineering Mechanics at Montana State University, the study is sponsored by the Montana State Highway Department and the Bureau of Public Roads. The project was inaugurated in June 1963, at which time four small watersheds in Montana were selected for intensive hydrologic instrumentation and study. Precipitation and streamflow data have been collected from the four areas since August, 1963. Additional meteorological data (wind speed and direction, soil moisture, and soil and air temperature) have been collected since July, 1964. The four instrumented watersheds are listed in Table I, which also indicates types and numbers of instruments in operation. The small watersheds are described in detail in Interim Report #1, "Selection of Small Watersheds," May 1965.

TABLE I - INSTRUMENTED WATERSHEDS

Watershed	Nearby Town	County	Area	Recording Raingages	Non-Recording Raingages	Water Stage Recorders	Weather Stations with Wind	Weather Stations without Wind
Bacon Creek	Harlowton	Wheatland	21.2 sq.mi.	2	3	1	1	1
Duck Creek	Brockway	McCone & Prairie	54.0	3	4	2	1	2
Hump Creek	Reedpoint	Sweetgrass	7.6	1	1	1	1	0
Lone Man Coulee	Valier	Pondera	14.1	2	2	1	1	1

The weather stations are described in Interim Report #3, "Weather Stations for Small Watersheds," July, 1965. The raingages and waterstage recorders are the subject of this report.

Need for Instrumentation - The study of four watersheds was proposed (as stated in the Prospectus) under Phase II of the project. The goal is to obtain data which can be correlated with the results of the U.S. Geological Survey "Small-Area Peak-Flow Highway Program" and thereby hopefully extend the usefulness of that program. The watersheds being investigated under the U.S.G.S. program are, almost without exception, rural areas for which no precipitation records are available. Prior to installation by the U.S.G.S., of crest stage gages, only occasional streamflow records for these watersheds were available.

Because precipitation and streamflow records are vital to any hydrology study, first concern upon inauguration of the Drainage Correlation Research Project was given to the selection of the four study areas and the installation of equipment to permit continuous measurement of these important quantities.

II. Preliminary Considerations

In the preliminary planning for the project, measurement techniques and equipment servicing were two subjects of major concern.

Precipitation Measurements - From the start it was evident that the only logical way of obtaining precipitation data would be through the installation and operation of a network of rain gages.

Most of the watersheds included in the U.S.G.S. crest-stage gage study are in remote, sparsely populated areas. A survey of commercially available instruments showed that recording rain gages are commonly designed to operate for one week without servicing, while non-recording rain gages require daily servicing when there is precipitation.

It seemed to be impractical for project personnel from Bozeman to visit the watersheds often enough to service raingages, so several possibilities for

local observers were explored. At least tentatively considered were Highway Department Personnel, County Extension Agents, Soil Conservation Service personnel, and Boy Scout, 4-H, and other similar civic groups. It was finally concluded that if the raingages were to be placed at remote points, far from habitations, it would be difficult, if not impossible, to obtain regular, reliable data, and that there would be considerable danger of vandalism from hunters or others. It seemed essential, therefore, that all raingages should be placed near ranch houses, and that arrangements be made with the rancher for him or some member of his family to assume the responsibility of servicing the instrument.

Streamflow Measurements - A variety of techniques may be utilized for measuring stream flow. Depth of flow records can readily be obtained by using a water stage recorder, but relating depth to discharge is often a difficult process. In the case of a small stream, a Parshall flume or weir is often installed to insure a fixed depth-discharge relationship. In a larger stream where a flume or weir is impractical, a culvert or fixed control may be utilized to permit determination of discharge from depth.

For the watersheds under consideration, peak discharges were expected to be too large to make flume or weir installation practical. The U.S.G.S. had established rating curves, however, for all their crest-stage gage instrumented watersheds. In some cases the crest-stage gages were installed near culverts, and in other cases they were installed near natural controls where current meter measurements could be made to establish reliable depth-discharge rating curves.

Since the watersheds selected for study under this project were to be U.S.G.S.-instrumented areas, it was felt that continuous discharge records could be obtained by installation of water stage recorders near the crest-stage gages, and utilization of the depth-discharge records the U.S.G.S. had developed for their gages. Water stage recorders which operate a month or longer without attention are available, so it seemed feasible that project personnel might be able to service these instruments.

Watershed Selection - With the decision to locate raingages at ranch houses a number of potential watersheds were eliminated because of lack of habitation. As has been mentioned in Interim Report #1, the number and spacing of ranches on the watershed were important factors in the final selection of the study areas.

Instruments Required - The number of raingages to be installed on each watershed was governed by the spacing of ranches. The original thinking was to have at least two recording and two non-recording raingages on each watershed. This pattern was modified somewhat after the areas were selected, to give a more nearly uniform intensity of gages. The original planning called for one water stage recorder on each watershed, but upon selection of Duck Creek as one of the study areas it was decided to install two recorders there, one on the main stem of Duck Creek, and one on a mojor tributary, East Duck Creek.

III. Equipment Selection

Recording Rain Gages - Commercially-built weighing type rain gages meeting Weather Bureau specifications were selected. Some thought was given to devising a telemetry system, whereby precipitation data could be transmitted, via radio or other means to a distant point, possibly to a central collection station on the watershed. This idea was rejected because of the costs involved, and because of the problem of providing power at points where electricity might not be available.

The tipping bucket type raingage, which is sometimes used by the Weather Bureau, was rejected because it is inoperative in freezing weather. The weighing type instrument may be used year around.

Three used raingages were loaned to the project by the U.S. Weather Bureau, and five new instruments manufactured by the Belfort Instrument Company were purchased.

The weighing type rain gage consists of four major elements, -- a collector, a weighing mechanism, a chart drive, and a housing. The gage is cylindrical, and

36 inches tall. The housing is a sheet metal case 13 inches in diameter enclosing the operating mechanism. It is fitted with a sliding door to provide access to the mechanism within. The collector, which forms the top of the housing, may be removed separately to provide access to the bucket in which the precipitation is collected. The top of the collector has an opening 8 inches in diameter through which precipitation falls into the bucket. The bucket rests on the platform of a spring scale, and the weight of the collected rainfall is transferred through a system of levers to a pen which moves across a paper chart. The chart drive is spring wound, and rotates a cylinder on which the chart is held.

Except for one of the gages loaned by the Weather Bureau, all are dual traverse, 12-inch capacity instruments. The pen moves upward across the chart while recording the first 6 inches, then reverses and moves downward to record the last 6 inches. The one Weather Bureau gage is single traverse, 6-inch capacity.

The chart drive mechanism in all cases operates one week on each winding. Different gear combinations are available to give one chart revolution per 24 hours, 96 hours, 192 hours, etc. When first installed, all the gages were adjusted to give one chart revolution per eight days. After a few months of operation, analysis of the data led to the conclusion that 96 hours per revolution would permit greater precision in determining rainfall intensities, so all the gears were changed accordingly.

Figures 1 and 2 show one of the recording raingages.

Non-Recording Rain Gages - The Weather Bureau standard 8-inch raingage was selected for installation on the project watersheds. This instrument consists of a cylindrical can 24 inches high and 8 inches in diameter. The collecting ring, which forms the top of the raingage, is fitted with a funnel, which directs precipitation into an inner brass tube having a cross-sectional area exactly one tenth that of the 8-inch opening. The depth of precipitation,

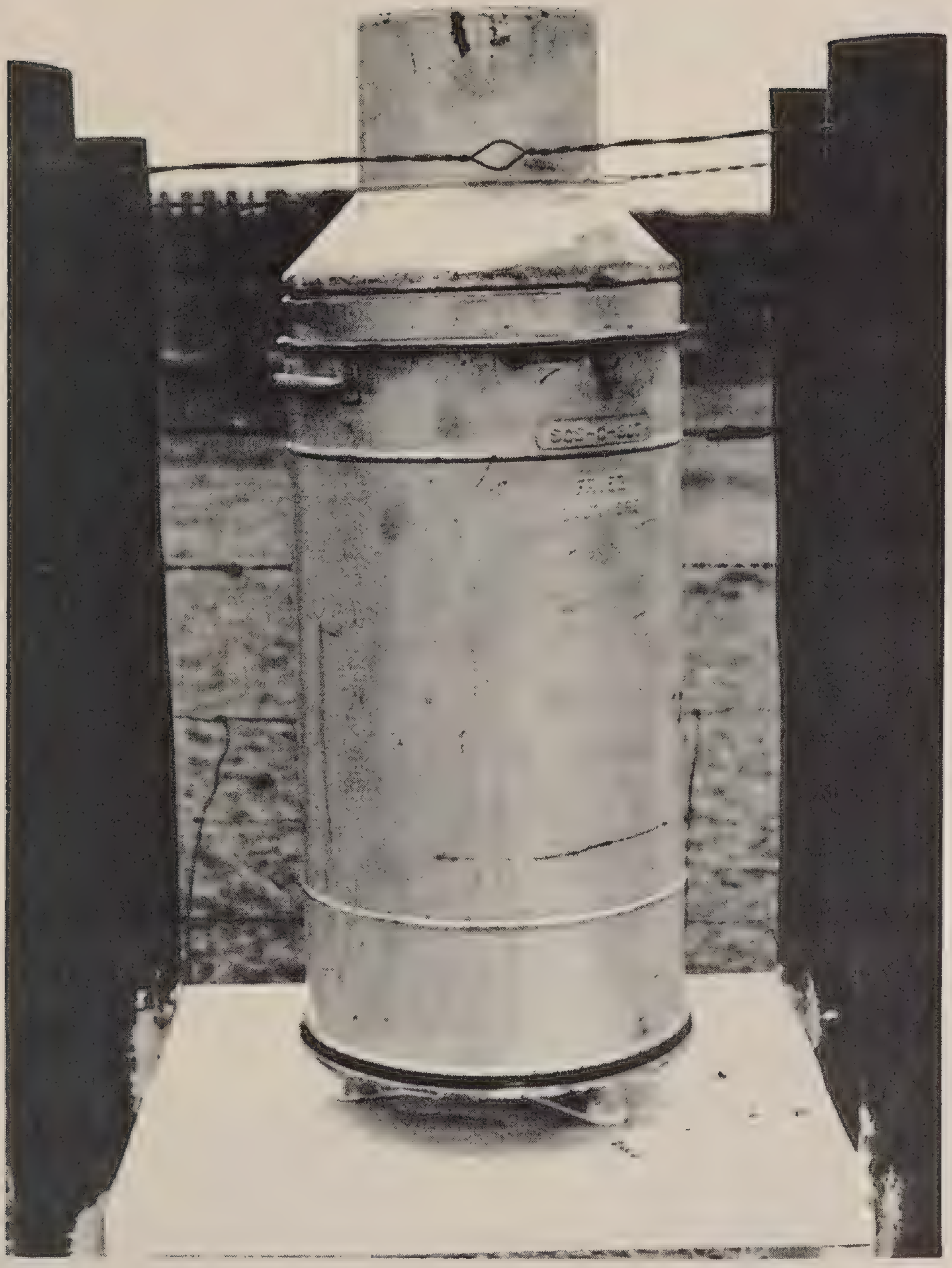

FIGURE 1 - Recording Rain Gage with 8-inch opening. Collector ring at top may be removed for access to collection bucket. Entire housing is raised to gain access to chart drive and weighing mechanism.

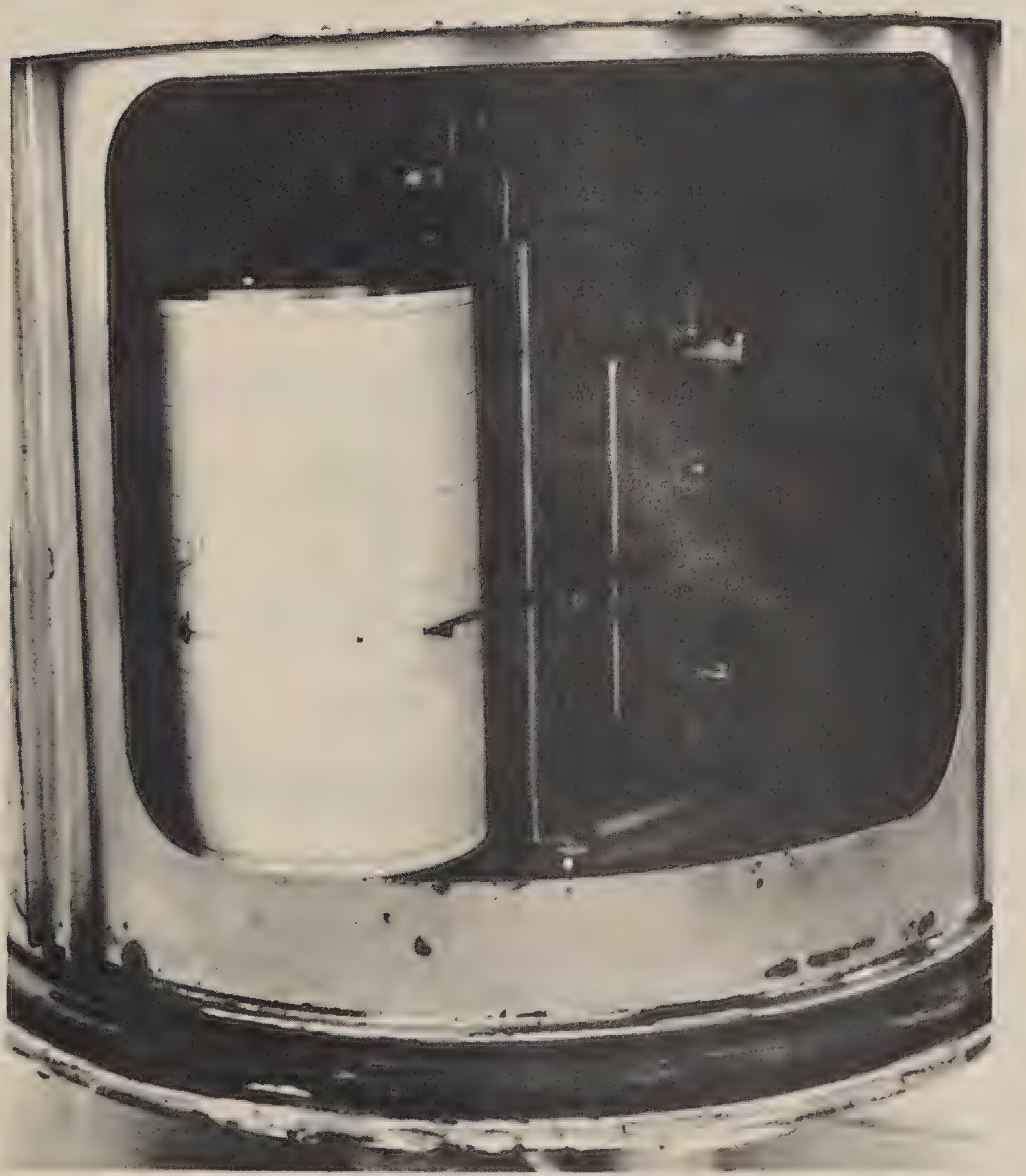

FIGURE 2 - Recording Rain Gage, with housing raised to show chart drive and weighing mechanism.

therefore, is magnified ten times for greater accuracy of reading. Depth is read with a redwood stick graduated in inches and hundredths. In event of a rainfall in excess of two inches, water overflows the brass tube, and is collected in the outer can. When this occurs, the amount retained in the brass tube is first measured and discarded, and the surplus from the outer can is then poured into the tube for measurement.

For winter operation the collecting ring and brass tube are removed, leaving the open 8-inch can in which snow accumulates. A measured amount of heated water is poured into the can to melt the snow, and all the water is then poured into the brass tube for measurement. The amount of precipitation is found by subtracting the heated water reading from the total measurement reading.

Several companies manufacture raingages to Weather Bureau specifications. Ten non-recording raingages, manufactured by Henry J. Green Instruments, were purchased.

A non-recording rain gage is shown in Figures 3 and 4.

Water Stage Recorders - Several manufacturers make water stage recorders. The Project paid for the reconditioning of two U.S.G.S.-owned Instruments Corporation recorders, which were then loaned by U.S.G.S. for use by the project. Three Leupold and Stevens Type A - 35 recorders were purchased.

The recorders are designed for installation in a shelter atop a stilling well at the stream edge. A small pipe from, or perforations in, the stilling well provide contact with the stream, and water rises in the well to the same level as that in the stream. A hollow float resting on the water surface is connected to the recorder by a steel tape, pulley, and counter weight mechanism. Rotation of the pulley as the float rises causes an inking pen to be moved across the paper chart. A chart drive mechanism causes the chart to advance at a predetermined rate. At the normal chart speed of 2.4 inches per day, a single 25-yard chart roll will last a year.

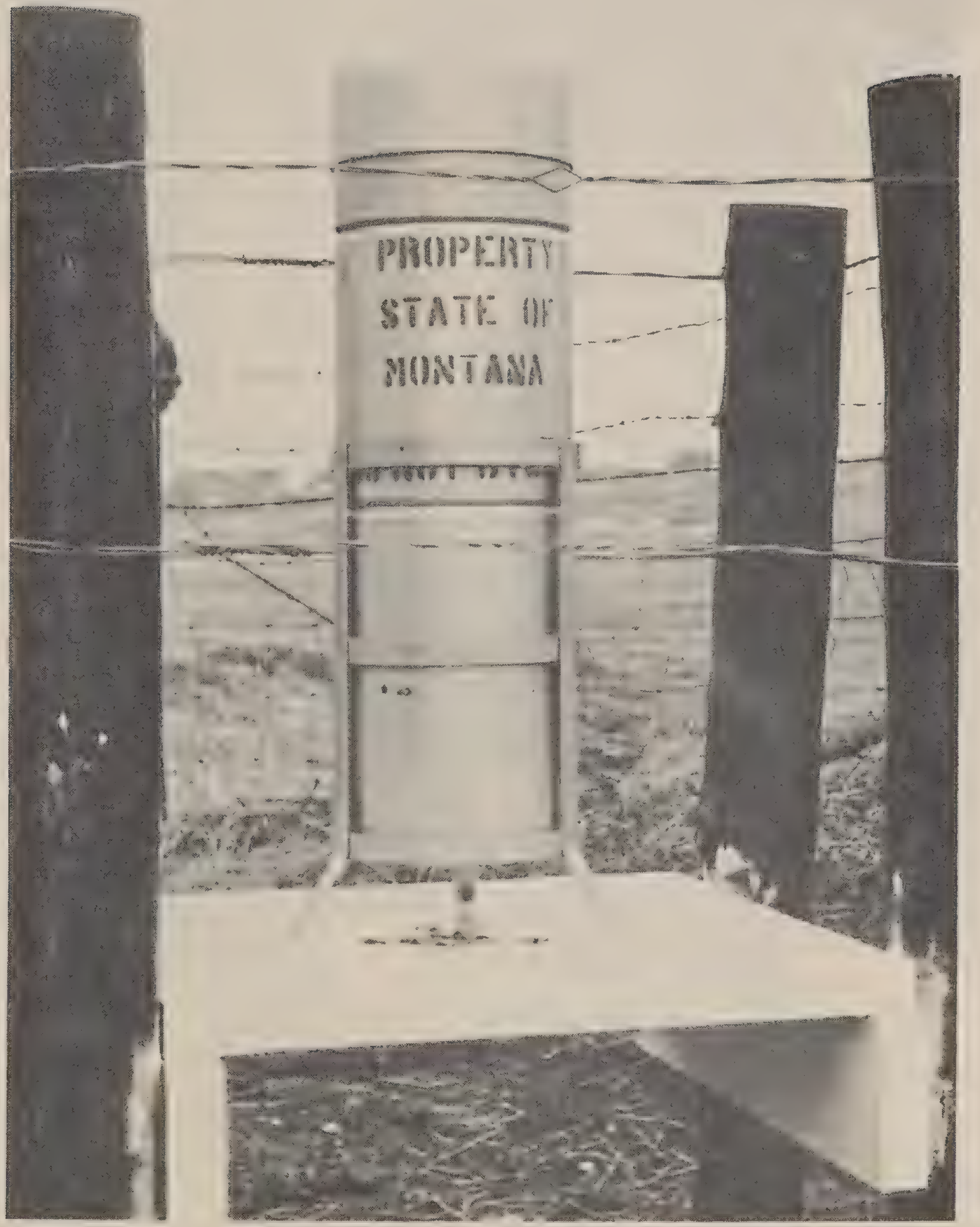

FIGURE 3 - Non-recording Rain Gage with 8-inch collecting ring in place.

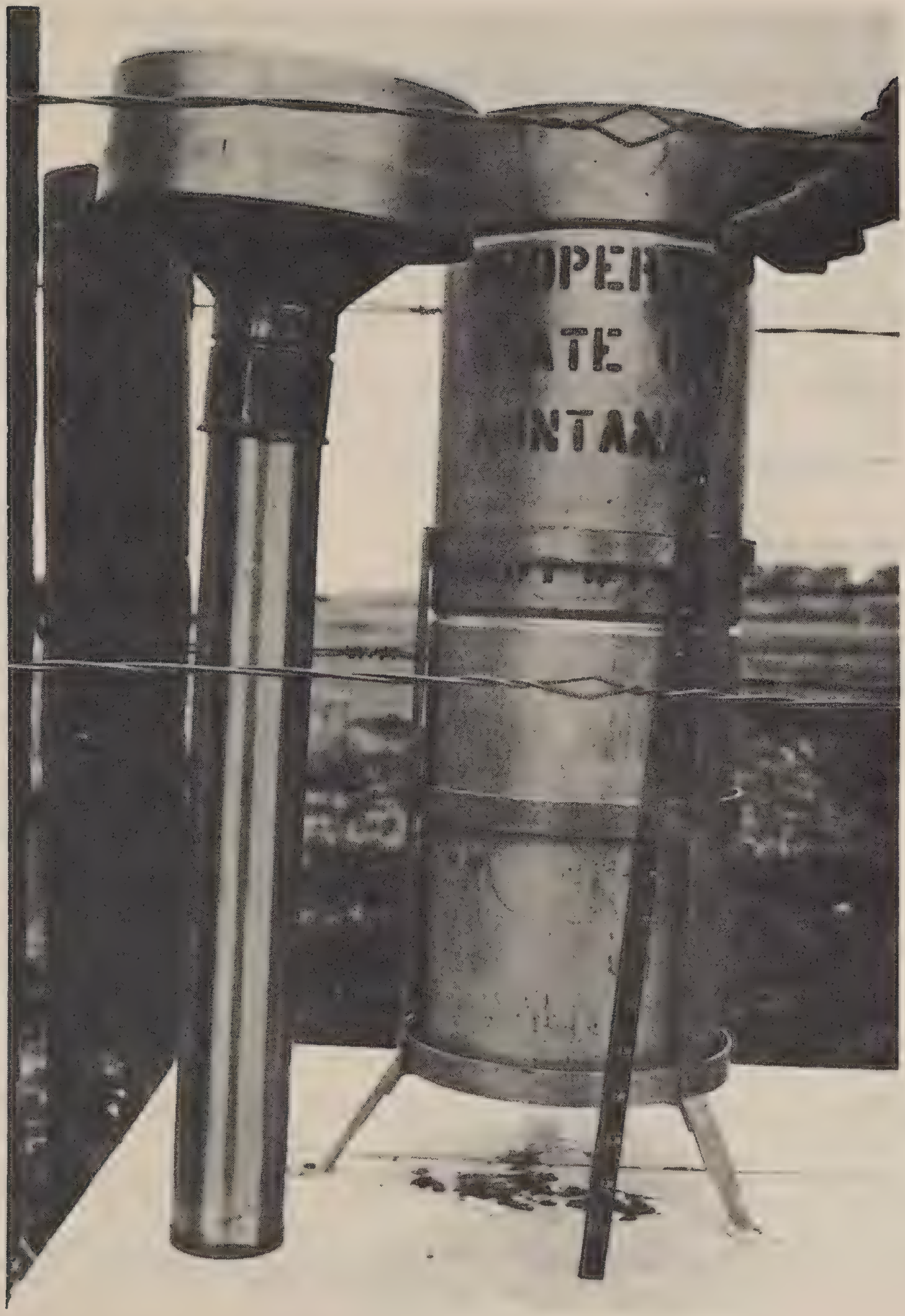

FIGURE 4 - Non-recording Rain Gage, collecting ring and brass tube removed. Measuring stick is inserted in brass tube to obtain precipitation readings.

The principal difference between the I - C and Stevens recorders lies in the chart drive unit. The I - C recorders are weight driven. Weights, which are suspended in the stilling well, fall in order to produce the power to drive the chart. Winding is accomplished by raising the weights. The maximum time between windings is governed by the height of the stilling well. As installed on this project enough height is available for about 60 days operation.

Several chart drives are made for the Stevens recorder. The drive selected is a negator spring type, which operates four months on one winding. The negator spring is a more expensive unit than the weight drive, but the additional time between windings was felt to be an important advantage.

IV. Installation

Eight recording and nine non-recording raingages, and five water stage recorders were installed between August 1 and September 20, 1963. An additional non-recording raingage (at Bacon Creek) was installed in August, 1964.

Raingage Installation - All the raingages, recording and non-recording, were mounted on wooden platforms about 12 to 18 inches above the ground. The 2-foot square platforms were each made of 2" x 12" planks supported by four creosoted fence posts. The $6\frac{1}{2}$-foot posts were set into the ground to a depth of two feet, and were designed to extend up nearly to the top of the raingages to provide protection from livestock and farm machinery.

Water Stage Recorder Installation - Pre-fabrication of stilling wells and recorder shelters was necessary prior to installation.

The stilling wells were all made from 24-inch corrugated metal pipe. They vary from 10 to 18 feet in length, and were fitted with flanges at the bottom for anchoring to concrete bases, and with metal rims on top to accommodate the recorder shelters. Each well has an 18" by 18" access door near the bottom for removing sediment, and several 1-inch holes for water to enter from the stream. Fabrication was done by a local welding shop.

Recorder shelters were made from 3/4-inch plywood, and are 30 inches square, by about 24 inches high. The shelters were sheathed top and sides with sheet metal. The lids are hinged, and may be raised to gain access to the recorders.

The original plans for recorder installation called for the pre-casting of concrete bases, 3 feet square and 4 inches thick, on which the stilling wells could be mounted. It was thought that the bases would provide adequate foundation support, and that further support could be afforded by attaching the stilling well to a bridge pier or abutment, or by guying with cables to buried anchors.

The installation at Hump Creek was carried out by project personnel, in accordance with the plans. Anchor bolts set in the concrete base were used to attach the stilling well, which was placed adjacent to the west concrete abutment of the Highway 10 bridge across Hump Creek west of Reed point. The installation is on the downstream (north) side of the bridge. Steel bands were fitted around the stilling well and bolted to 2" x 6" boards which had been "nailed" to the concrete wall with "Ramset"-fired nails. The U.S.G.S. crest-stage gage, incidentally, is attached to the east abutment of the same bridge, on the upstream (south) side.

Experience gained in the Hump Creek installation, which was the first to be completed, resulted in some revised planning regarding the remaining installations. It was concluded that the installations could be made more economically and efficiently by local contractors in each of the areas rather than by project personnel, and that concrete bases should be "cast-in-place" for greater support rather than "pre-cast." The stilling well could be temporarily supported in its approximate position, and concrete poured around its base. By setting the base in concrete about six inches, the anchor bolts were deemed to be unnecessary, and were not used. All the remaining installations, therefore, were made by local contractors, and included cast-in-place bases.

The two installations on Duck Creek were each made by attaching the stilling well to a county bridge. Steel bands were passed around the stilling well and a timber bridge pile, and were fastened to the pile by lag screws. The East Duck Creek installation is on the downstream (west) side of the bridge on State Secondary Highway 253. The crest-stage gage at that location is likewise on the downstream side of the bridge, but attached to a pier near the south end of the bridge, whereas the recorder installation is near the north end of the bridge. The main Duck Creek installation was made on the downstream side of a county bridge, with the stilling well attached to the center pier. The crest-stage gage is attached to the east abutment on the downstream side of the same bridge.

At Lone Man Coulee and Bacon Creek, bridges were not conveniently located, so the water stage recorder installations at these watersheds are supported by guy cables running from the top of the stilling well to anchor bolts set in concrete. Each installation utilizes four guy cables. The anchor blocks are cubical, about two feet on a side, and were cast-in-place in holes that had been dug in the stream bank. At these two sites plank walkways extending from stream bank to stilling well were necessary. At Lone Man Coulee, two crest-stage gages are used, one upstream and one downstream from a 72-inch culvert beneath a county road, about 250 feet upstream from the water stage recorder. At Bacon Creek the crest-stage gage is attached to a fence post about 50 feet upstream from the recorder.

Figures 5,6,7, and 8 show the Bacon Creek recorder installation.

V. Instrument Operation

The raingages and water stage recorders have all operated continuously since September, 1963 (except for one non-recording rain gage which was not installed until August, 1964.) Maintenance and operation problems have been relatively few, but are discussed below.

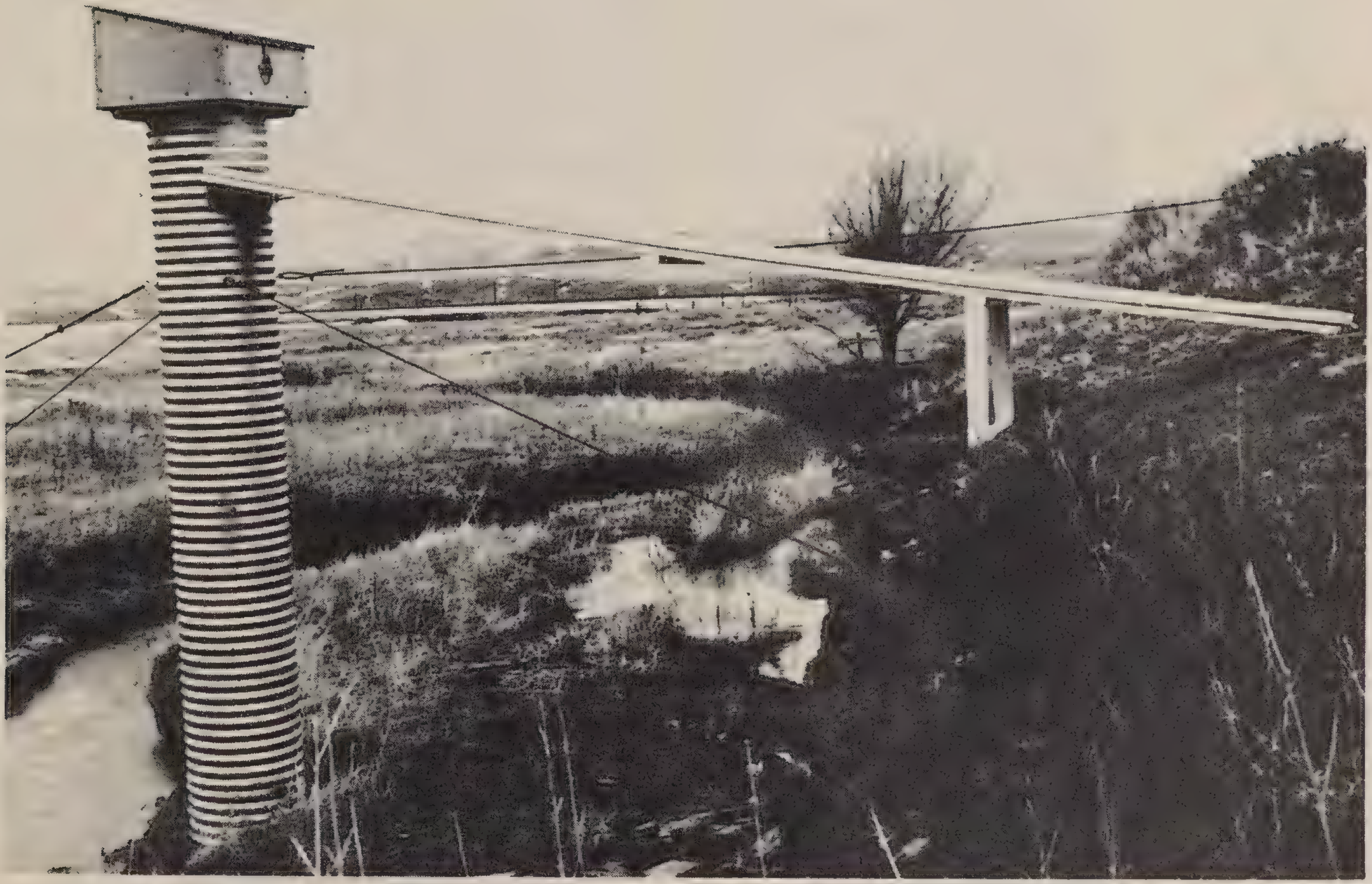

FIGURE 5 - Water Stage Recorder installation on Bacon Creek near Harlowton. 24-inch corrugated metal stilling well is 14 feet tall. View is looking downstream in Bacon Creek.

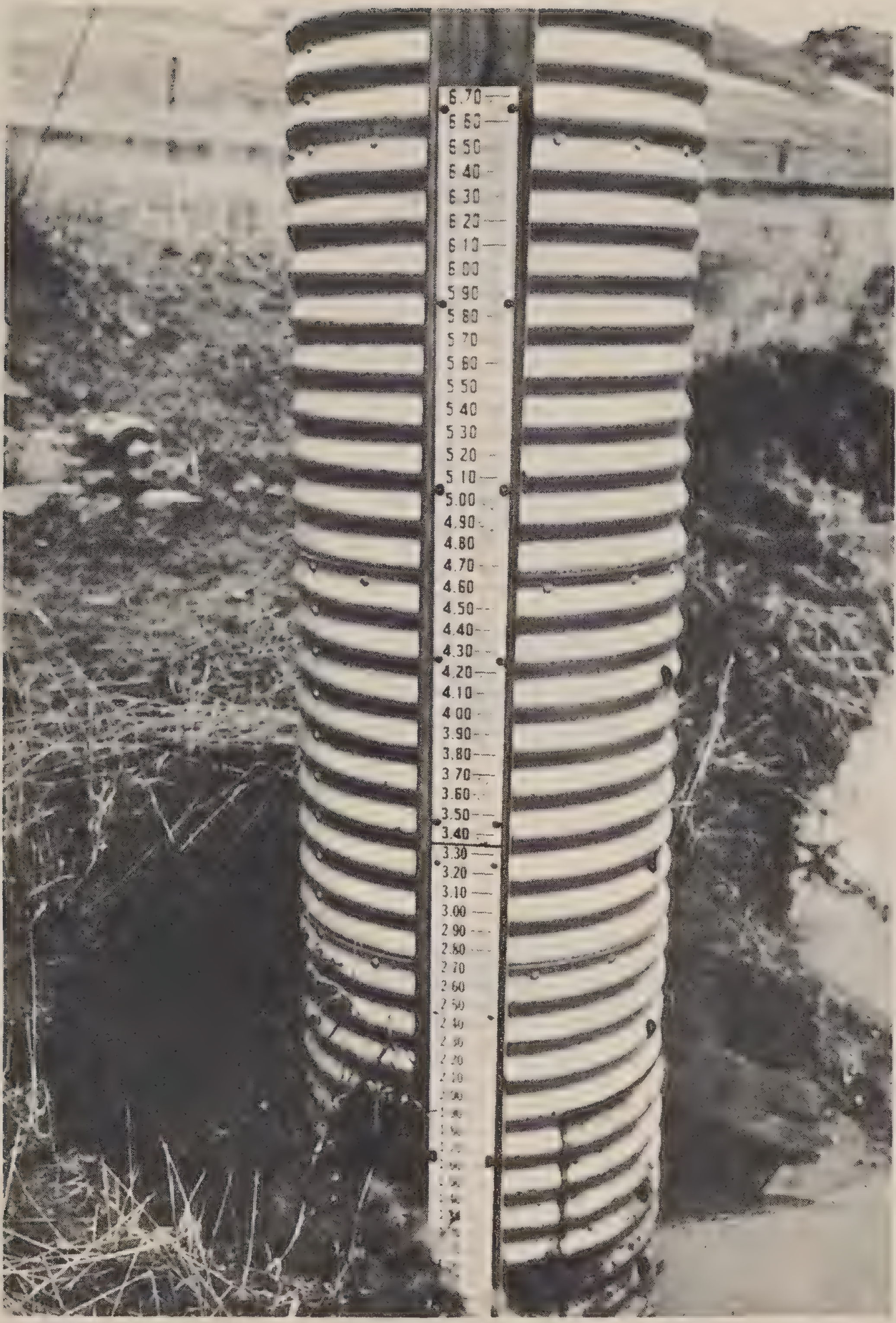

FIGURE 6 - Detail of water stage recorder stilling well showing staff gage used for visual check of water level. Clean-out door, and holes to permit water to enter the well, are visible at right of well.

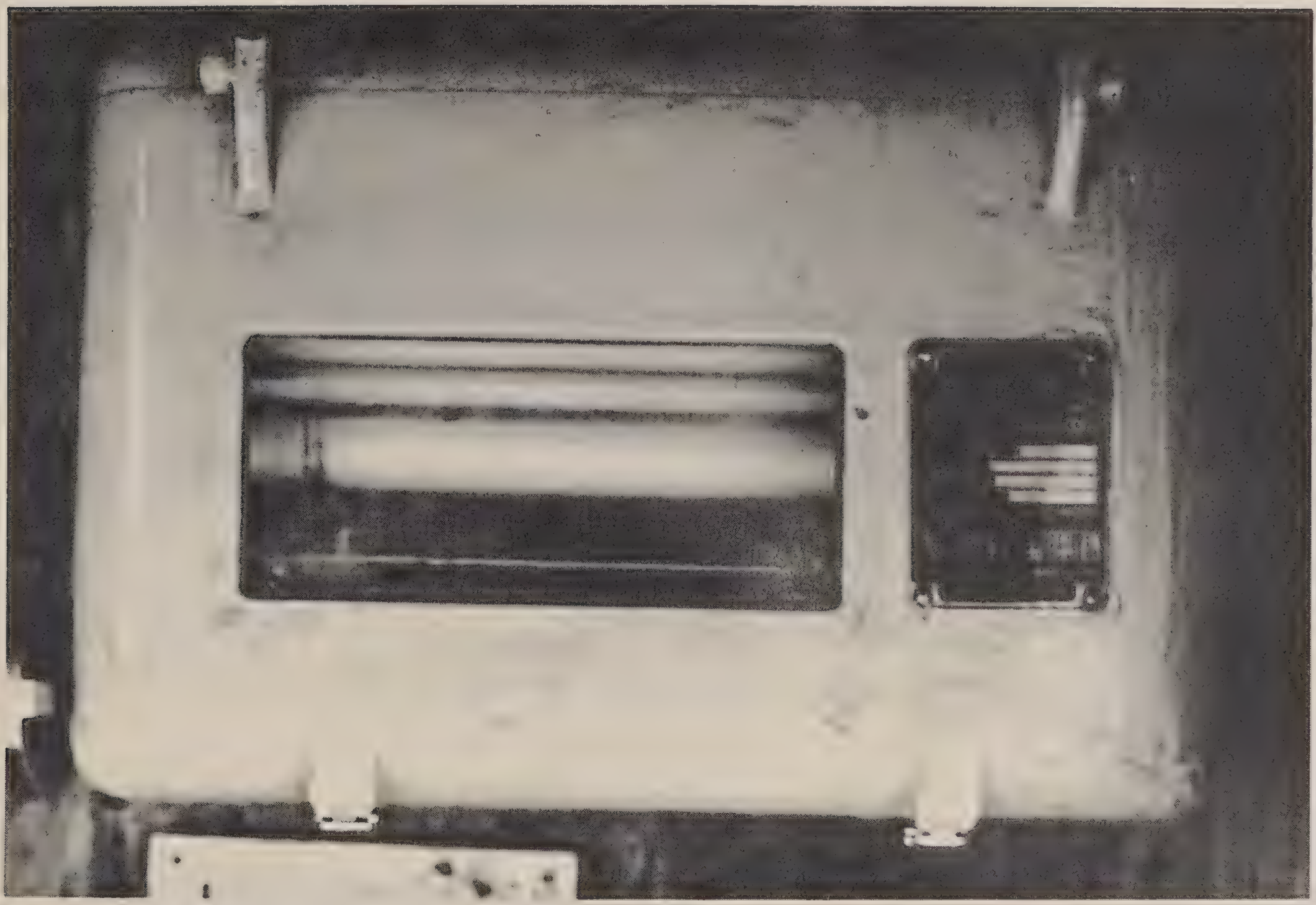

FIGURE 7 - Water Stage Recorder, top view, This is one of the Instruments Corporation recorders loaned to the project by the U.S. Geological Survey. Float tape seen at lower left corner operates a pen, by turning the pulley. At extreme upper left corner is the cable to the chart drive weight.

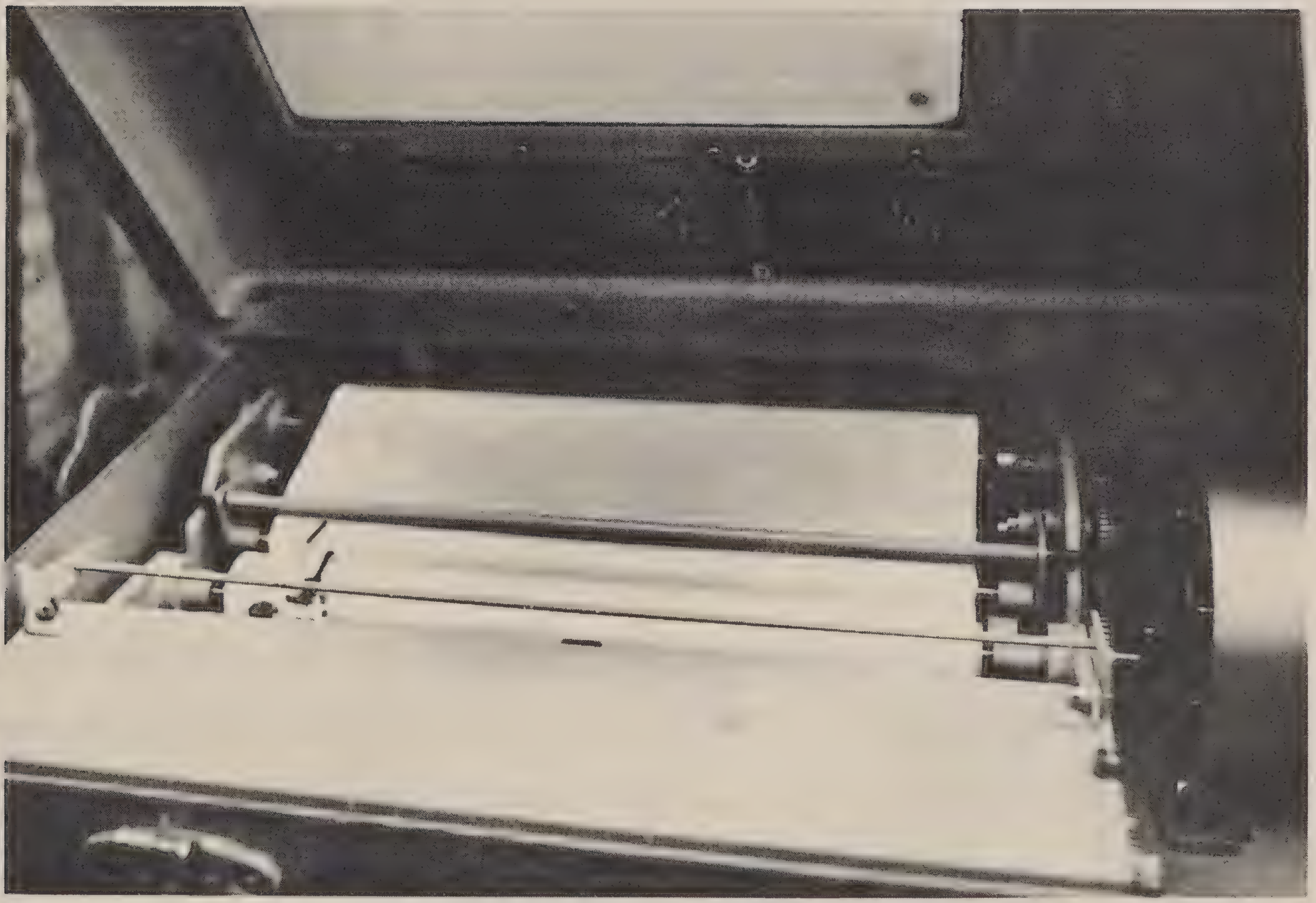

FIGURE 8 - Water Stage Recorder, with cover raised. Pen is resting near left side of chart. Chart drive mechanism on the right is weight driven.

Recording Rain Gages - These instruments require calibration and occasional lubrication to operate accurately. A set of raingage weights was purchased to facilitate calibration. Each instrument is calibrated in the field annually. The gages which were purchased new have required very little adjustment. The used Weather Bureau gages have required more attention, and two of these instruments were brought into Bozeman in February, 1965 for more thorough servicing than was possible in the field. The chart drive mechanisms of the Weather Bureau instruments were cleaned and adjusted before installation in 1963, and the clocks have generally operated very faithfully to date. An occasional clock stoppage does occur, particularly in extremely cold winter weather. The observer sometimes fails to completely wind the mechanism, and this will cause the clock to stop before the week is over. The pen which marks the precipitation record on the chart, and the pen arm to which it is connected, are rather easily broken. It has been necessary to replace pens on three raingages, but no pen arms have been broken to date.

A small quantity of oil is kept in the recording raingage bucket at all times, to prevent evaporation of water which has been collected. The oil is replaced each time the bucket is emptied, usually once a month or so, depending upon the amount of precipitation that has occured. Usually the bucket is emptied when it contains 4 or 5 inches of accumulated precipitation. During winter months a solution of calcium chloride crystals and water is prepared, to be added to the oil in the raingage bucket. This solution keeps the accumulated precipitation melted. It usually is necessary to replace the calcium chloride once or twice during the winter. The U.S. Weather Bureau, to date, has supplied sufficient quantities of calcium chloride for all the project raingages, at no cost.

Some hydrologists recommend the installation of slatted wind shields around the raingage to improve the efficiency during windy periods. To

date no wind shields have been installed on project raingages. The raingages vibrate considerably in strong winds, and the vibration is transmitted very noticeably through the pen to the chart. The vibration is undoubtedly a major cause of the raingages getting out of calibration.

Non-recording Rain Gages - The non-recording raingage has no moving parts, and hence there is no way for it to get out of adjustment. Except for one or two instances of a broken measuring stick, no maintenance problems have been encountered. Operation of the raingages has been entirely satisfactory, except for two cases in which the spot originally selected for installation proved to be subject to drifting snow. In each of these cases, the raingage was moved to a more favorable location on the same ranch.

Water Stage Recorders - The water stage recorders have functioned mechanically very satisfactorily. Because of the nature of the data collected, and the ephemeral streams on which they are installed, however, they require a considerable amount of attention in the field.

In the two years of the operation, only one instance of chart drive failure has occurred. That was during a prolonged period of sub-zero weather at Duck Creek. On one or two occasions the chart paper has failed to advance because of mis-threading. In freezing weather, if water is in the stilling well, the float may become frozen in the ice, and hence may fail to register water level changes. At stations where this condition occurs frequently, the float has been blocked up slightly above the water surface. In the event of an increased stream flow, the float will be lifted off the blocking, and will then register correct water level changes.

Several problems are connected with the adjustment of the pen on the chart. Adjustment begins by installing a staff gage outside the stilling well, with the zero of the gage coincident with the concrete floor of the stilling well, or at about the same level as the lowest point on the stream bed. This establishes the recorder datum. Levels are run to tie the recorder datum to

the crest-stage gage datum. With water flowing in the stream, wave action and transfer of kinetic to static head may cause the outside staff gage to give a false indication of the true water level in the stream, so a graduated steel tape, with weight attached is mounted in the recorder box beside the recorder. By properly adjusting the tape, it can be used to determine water level. The weight and tape are lowered until the weight just touches the water surface, and the gage height noted.

With water flowing in the stream, the pen on the recorder can be easily adjusted to record the same value as the outside gage or the inside weight tape. A further check is afforded by the float tape which at most installations is also graduated. The float tape, which actuates the pen, may be adjusted in length until an index, mounted on the recorder, will indicate the proper gage reading. With no water in the stream, which usually is the case when the recorder is visited, the float will rest on the concrete floor, or on silt if such has accumulated in the well. The depth of water required to cause the float to start rising varies from one installation to another, so in this situation it is difficult to determine what the proper pen setting is. In some cases it was necessary to haul water in 50-gallon drums to the site so the stilling well could be filled with enough water to actuate the float, and perform necessary adjustments to the various components. The instruments have maintained their adjustment fairly well in most cases. Major exceptions have occurred at Lone Man Coulee and at Duck Creek. At Lone Man Coulee cattle rub against the stilling well when the stream is low, and on several occasions have eventually caused one of the adjustment screws to work loose. This is sufficient to cause the pen to record improperly. No permanent solution has been found for this situation. At Duck Creek the county bridge used for support of the stilling well was so weak that traffic caused vibration of the recorder, and this condition caused frequent maladjustment of the instrument. The problem was relieved in 1964 by removing

the recorder, and installing it at a new location several hundred feet downstream. At the new site the stilling well is supported by guy cables and concrete anchors in a similar fashion to the Bacon Creek and Lone Man Coulee installations.

VI. Data Analysis

Reduction of data from the raingages and water stage recorders has been kept up-to-date since the instruments were first placed in operation in 1963. Data are recorded on sheets which may later be used by key punch operators in preparing input cards for the electronic computer.

Data from some storm periods are being studied in detail but there has not yet been a complete analysis of data.

Obtaining discharge values from water stage recorder data is a necessary, and sometimes difficult, interim step in the processing of streamflow records. The U.S.G.S. has developed stage-discharge curves, based on flow formulas, current meter measurements, or slope-area measurements (or a combination of these) at each of the crest-stage gage stations. Since the water-stage recorders are, in each case, located near the crest-stage gages, the same curves may be used in converting stage data from the recorders into discharges. The U.S.G.S. has cooperated greatly in making special measurements at project watersheds, to improve or supplement the stage-discharge curves. At one or two watersheds, notably at Hump Creek, the stage discharge curve is still poorly defined, and it has not been possible to assign discharges to all depth readings.

VII. Conclusion

The preceding report has described the instrumentation of four watersheds for the purpose of measuring precipitation and streamflow. Data have been collected at these watersheds since August, 1963.

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DRAINAGE CORRELATION RESEARCH PROJECT

Interim Report #3

July, 1965

WEATHER STATIONS FOR SMALL WATERSHEDS

by T.T. Williams and C.P. Edwards

I. Introduction

The Drainage Correlation Research Project, a study being conducted by the Civil Engineering Department at Montana State University, and sponsored by the Montana State Highway Department and Bureau of Public Roads, is an investigation of peak rates of runoff from small watersheds in Montana. Since inauguration of the project in June, 1963, four small watersheds in Montana have been instrumented, and meteorological and streamflow data are currently being obtained from them. The four watersheds being studied are listed in Table I, which also indicates types and numbers of instruments in operation. The small watersheds are described in detail in Interim Report #1 entitled "Selection of Small Watersheds," which was prepared May 6, 1965.

TABLE I - INSTRUMENTED WATERSHEDS

Watershed	Nearby Town	County	Area	Recording Weighing Rain Gages	Non-Recording Std 8" Rain Gages	Continuous Water Stage Recording	Weather Stations with Wind	Weather Stations without Wind
Bacon Creek	Harlowton	Wheatland	21.2 sq.mi.	2	3	1	1	1
Duck Creek	Brockway	McCone & Prairie	54.0	3	4	2	1	2
Hump Creek	Reedpoint	Sweetgrass	7.61	1	1	1	1	0
Lone Man Coulee	Valier	Pondera	14.1	2	2	1	1	1

The raingages and waterstage recorders were all installed during August and September 1963, and data have been obtained continuously since that date.

Installation of these instruments is described in Interim Report #2, "Precipitation and Streamflow Instrumentation for Small Watersheds," July 1965. The Weather Stations, which are package systems for the continuous measurement of air and soil temperature, soil moisture, and wind speed and direction, were installed during the summer of 1964. These latter instruments are the subject of this report.

Need for Weather Stations - In the initial stages of the project, plans were made to measure only precipitation and streamflow. It was not until a preliminary study of past records had revealed that snowmelt frequently seems to be an important factor in peak discharges from small watersheds, that measurement of meteorological phenomena was considered.

In order to effectively analyze a snowmelt flood, it was felt that index measurements of wind speed and direction would be indispensable, both for snow drifting analyses and for studies of snow melting periods. Also essential to the snow melt analyses are air temperature, soil temperature, and soil moisture content.

The decision to provide instrumentation to measure these phenomena initially envisioned for each watershed a commercial wind recording system, two or more commercial two-channel recording thermographs (to record daily maximum and minimum air and soil temperatures), and an undetermined number of gypsum or fiberglass block soil moisture elements. Since no commercial equipment could be found that would record soil moisture levels from the blocks, it was anticipated that a moisture meter would need to be purchased, and project personnel assigned to visit the watersheds and measure soil moisture levels regularly.

The instrumentation as originally planned had several disadvantages, chief of which were the fact that local observers (usually ranchers or their wives) would be required to service several pieces of delicate scientific equipment,

in addition to the raingages they were already tending; and that project personnel would be required to do a tremendous amount of travelling to get regular soil moisture data. It was in an effort to overcome these obstacles that the Electronics Research Laboratory (a unit of the Electrical Engineering Department) at Montana State University was invited to study the requirements and make recommendations. The Electronics Lab study, and their proposal to develop "package system" weather stations, are discussed below.

II. Survey of Commercial Equipment

Most meteorological instruments fall into two categories. The first category contains single parameter measuring units which may or may not be capable of recording their outputs. Such instruments as mercury thermometers and wind vanes are typical. The second category contains multiparameter measuring instruments which process and record the inputs of several transducers. Systems in this category are usually expensive and are custom built to do a specific job.

In choosing between the two categories, it is also necessary to consider the operator requirements. Money that is saved by buying a group of inexpensive instruments is often spent for labor to operate and maintain them. And, of course, in any data collection system prime consideration should be given to the cost of placing the data, in usable form, in the hands of the researcher. If a great deal of data is to be collected, it is often advantageous to initially record it in computer digestible form. However, the glamour of a computerized program should not mask the possibility of reduced cost and increased insight by using an optimum combination of manual reduction and computer regression analysis.

With this brief analysis of the overall problem, the specific needs of the project can be discussed.

The project requires:

1. Economical operation contingent on necessary accuracy and reliability.

2. Unattended operation with only occasional servicing.
3. Utilization of unskilled personnel for routine service.
4. Continuous records.

The parameters to be measured at one-half hour intervals are:

1. Average wind speed (30 min average) 0-80 mph (4 stations)
2. Wind direction 0-360° true (4 stations)
3. Air temperature, 2 elevations, -60 to +130°F (8 stations)
4. Soil temperature, 3 depths, 0° to 100°F (8 stations)
5. Soil moisture by resistance, 3 depths, 200 ohm to 1 meg ohm (8 stations)

A survey of commercial equipment made by both the Civil Engineering Department and the Electronics Research Laboratory indicated that no one system was available to perform this task. Indeed, it was found that there was no recording soil moisture system available in any form. Further, because of the unique operator problem, it seemed very desirable to combine all measuring functions into one compact unit that would require a minimum time of one month between servicings.

III. Development, Design and Production of the Weather Stations

The design of an automatic weather station, once the input parameters and ranges are established, requires the sequential solution of the following basic questions:

1. Type of Transducers?
2. Method of recording?
3. Connecting electronics?
4. Commutation of inputs?
5. Timing of interrogation?
6. Mechanical configuration?

The choice of transducers is the most critical since it directly influences the accuracy and reliability of the whole system. Because of the strong winds

and wide temperature range that would be encountered by the wind transducers, a rugged cup anemometer and single tail direction vane built by the Belfort Instrument Company were chosen. These units require very little maintenance and have many years of operating history.

Precision thermistors made by the Yellow Springs Instrument Company were chosen for the measurement of air and soil temperature. They have a basic accuracy of ±.2°C over the operating range. In order to obtain the proper radiation environment for free air temperature measurement, the thermistor was mounted between two aluminum dishes. These were painted black on the side facing the thermometer and brightly polished on the other side. The soil temperature thermistors were encapsulated in epoxy for additional protection.

Soil moisture is a very difficult parameter to measure with precision. A method that has been used for many years, where moderate accuracy is sufficient, utilizes a gypsum block containing two electrodes. If an alternating voltage is applied across these electrodes (to avoid polarization) the resulting current is a function of the moisture of the surrounding soil. Although this technique is the most suitable for this project, it unfortunately requires considerable time to calibrate the gypsum blocks to each of the soil types at the various stations. A gypsum block manufactured by the Delmhorst Instrument Company was chosen. This element uses a plastic binder that greatly improves the life of the device.

The method of recording is dictated by the amount of maintenance required, the data reduction problems and the necessary accuracy. Of course, cost is always a constraint and in this case, an analysis of the final data reduction costs must be included. After considerable investigation, it was decided to use the Rustrak recorder. While the use of a computer digestible tape punch would probably be desirable, the added cost of both the recorder and a recorder system were out of line with the project budget. In addition, graduate students could be easily made available to reduce the data off of the Rustrak tape.

The Rustrak recorder is of very simple design and writes on pressure sensitive paper so that no ink is required. Since it is necessary for the recorder to be on only a short time each one-half hour, the paper supply lasts for over one month. Some skill is necessary to load the paper but this can soon be acquired.

A considerable amount of electronics is necessary to convert the outputs of the various transducers into a form suitable for the recorder. To insure a high degree of reliability, all circuits were designed with transistors and solid-state components. Well-regulated power supplies were chosen so that variations in power line voltage would not effect the accuracy of the readings. Adequate calibration controls were included to insure that the stations can be kept in proper calibration.

Since the recorder has only one input and there are 8 to 10 transducer outputs, it is necessary to automatically switch (commutate) these into the recorder. A gold plated telephone type stepper switch was chosed to provide reliable commutation. Every one-half hour the stepper switch is stepped to each of the transducer outputs and the recorder makes a short mark indicating the magnitude of the transducer output. The first channel (wind speed) is identifiable by a slant line and the remaining channels always follow in the same sequence so that it is possible to easily identify the channel of interest.

The station is turned on by a clock switch every one-half hour. The drive motor is synchronous so that the timing accuracy is quite good (the equivalent of a regular electric clock.) This switch starts the recorder and initiates the stepper switch. After the stepper switch has completed the last step, the recorder is turned off. This cycle repeats itself every one-half hour. To make positive identification of time, a second timer is used to double the recording time every 24 hours. Thus at midnight the marks indicating the magnitude of the various transducers are twice as long as normal.

A small metal cabinet was chosen for the electronics and recorder. A plug on the rear connects this unit with the transducer cable. Figures 2, 3, and 4 show the front, rear and interior of the cabinet respectively. The dial for the 24-hour clock can be seen on the left-hand side in Figure 3.

All of the transducers were prewired to a junction box located inside of the lower instrument shelter (see Figure 1). They are connected via a 12 conductor cable to the main unit in the Rancher's house.

All construction of the system was done by the Instrumentation Group of the Electronics Research Laboratory. Graduate students were used where practicable to assist with both the design and construction. The more interested reader is referred to the "Operation and Maintenance Manual for the Civil Engineering Weather Station" (Electronics Research Lab Report) for more detailed information.

IV. Installation

Installation of the eight weather stations was accomplished between June 29 and July 31, 1964. The project supervisor and three student assistants devoted full time to installation during that period. An Electronics Research Lab engineer supervised the electronic installation at the first station to be installed.

Transportation

To haul the supplies and equipment necessary for installation, a truck and semi-trailer belonging to the Mechanical Engineering Department at Montana State University were utilized.

The trailer consisted of a 20-foot enclosed van. The outfit had been used for previous research studies, but was idle at the time, and hence was available continuously during the period it was needed. Installation, the year before, of raingages and water stage recorders, had required the short-term rental of university trucks, with strict deadlines for their return to the campus. With the

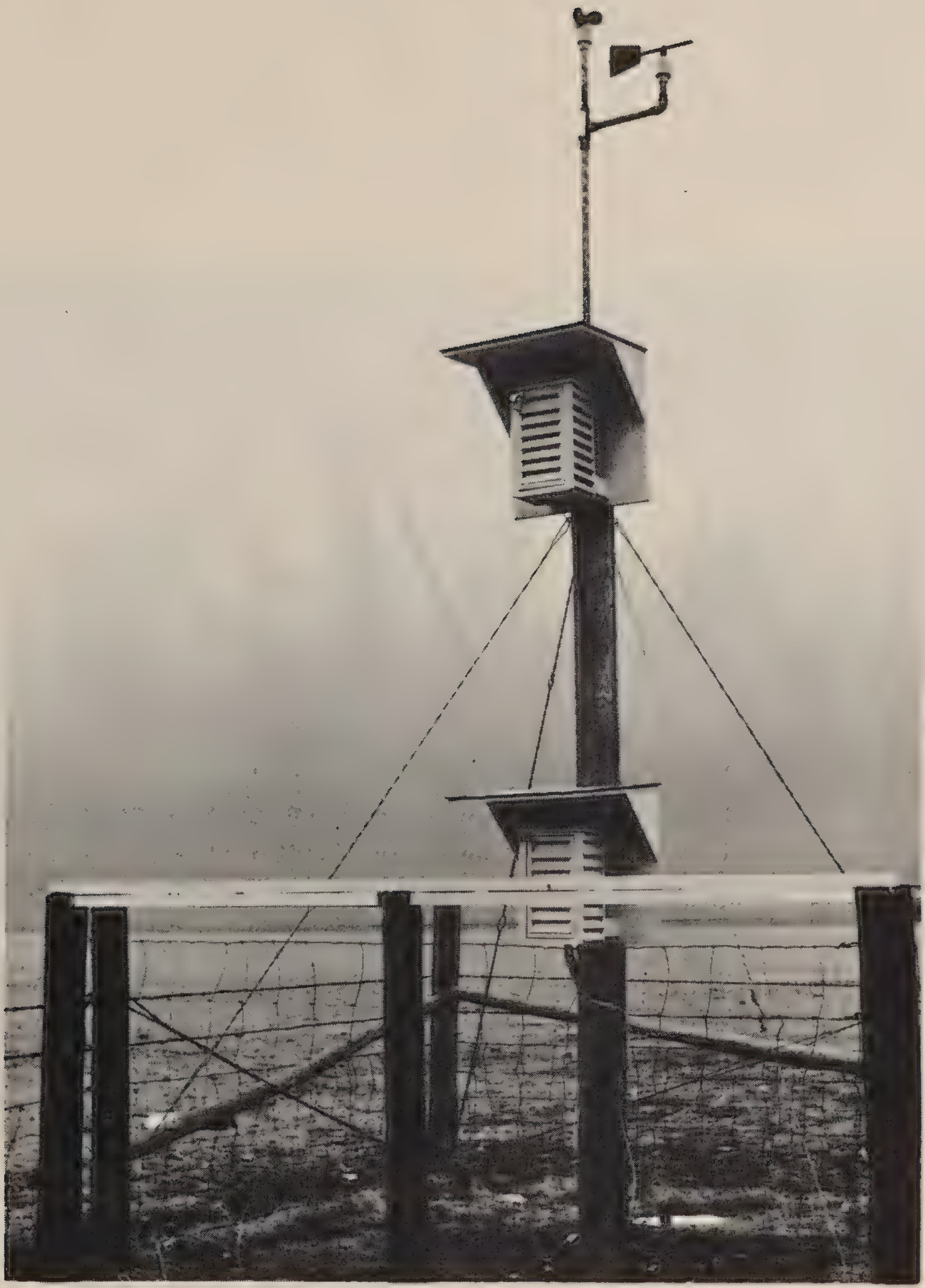

FIGURE 1 - Weather Station. Terminal board for all instrument wiring is located in lower thermistor shelter. Wires to soil moisture-temperature units are visible, as well as cable to recorder in ranch house. Instruments are within a 10-ft square fenced enclosure.

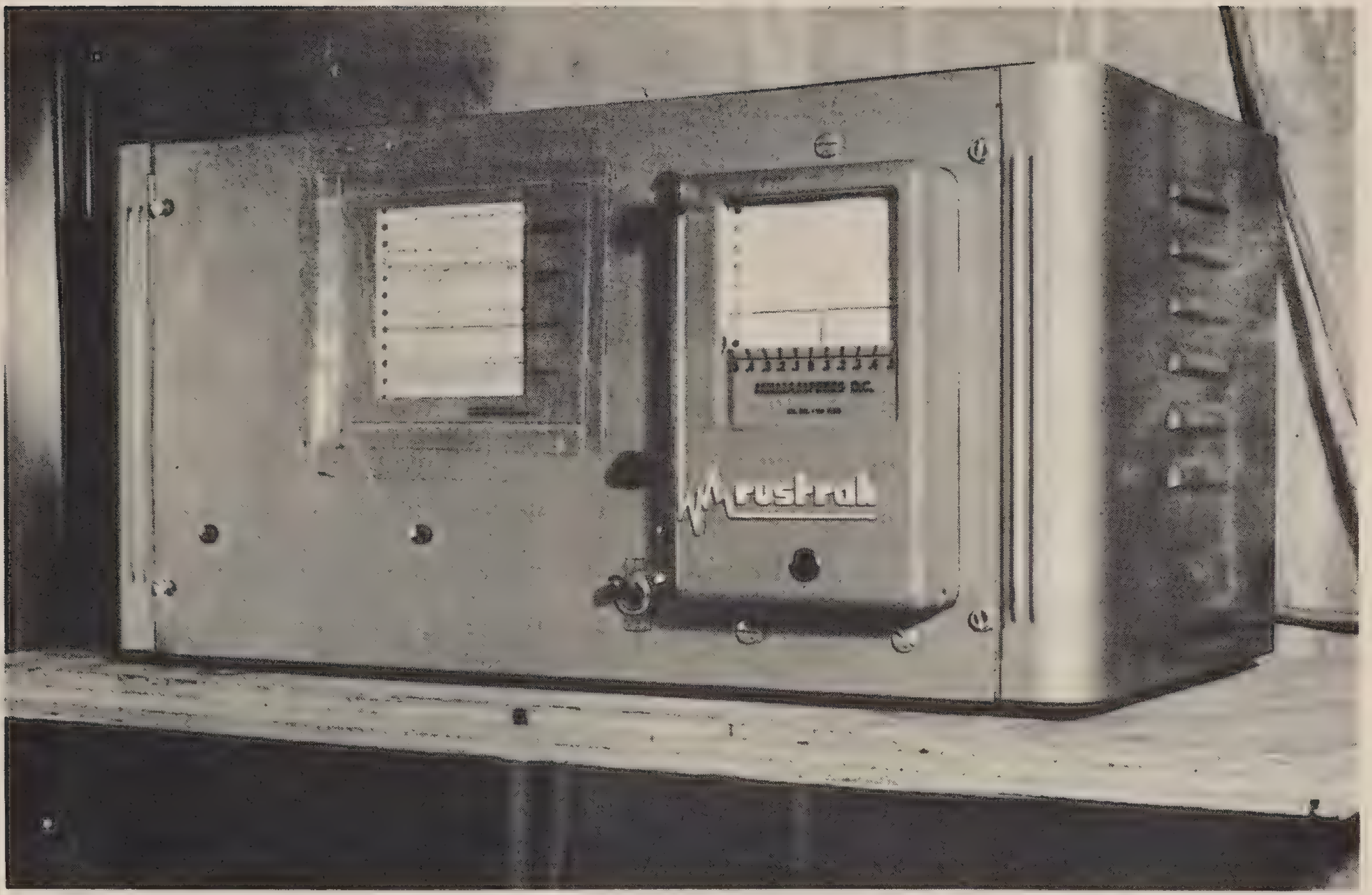

FIGURE 2 - Recorder, front view. The Rustrak unit utilizes pressure sensitive strip chart paper.

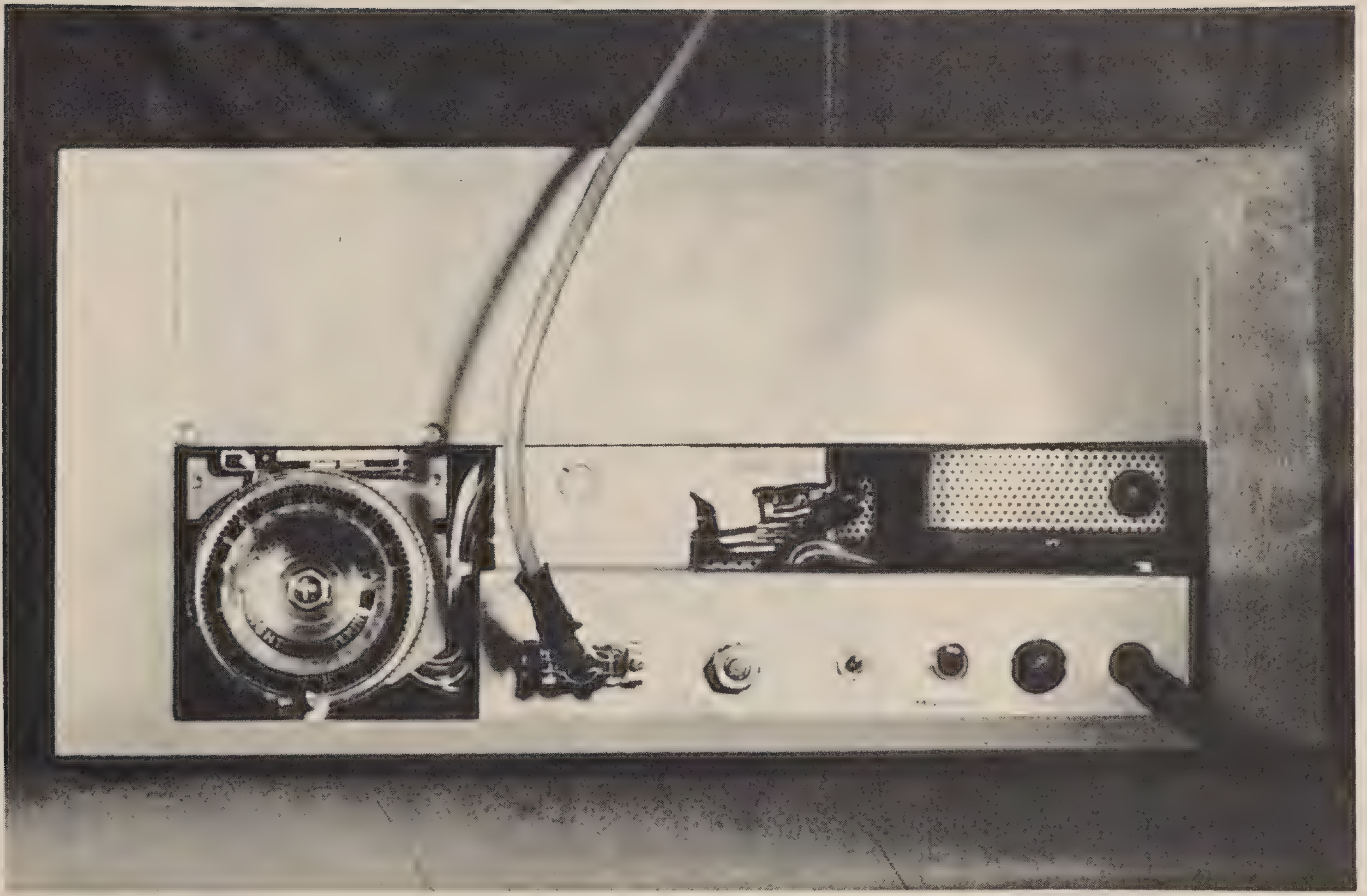

FIGURE 3 - Recorder, rear view. The marker switch, visible at the left was installed after the recorder had been in operation several months.

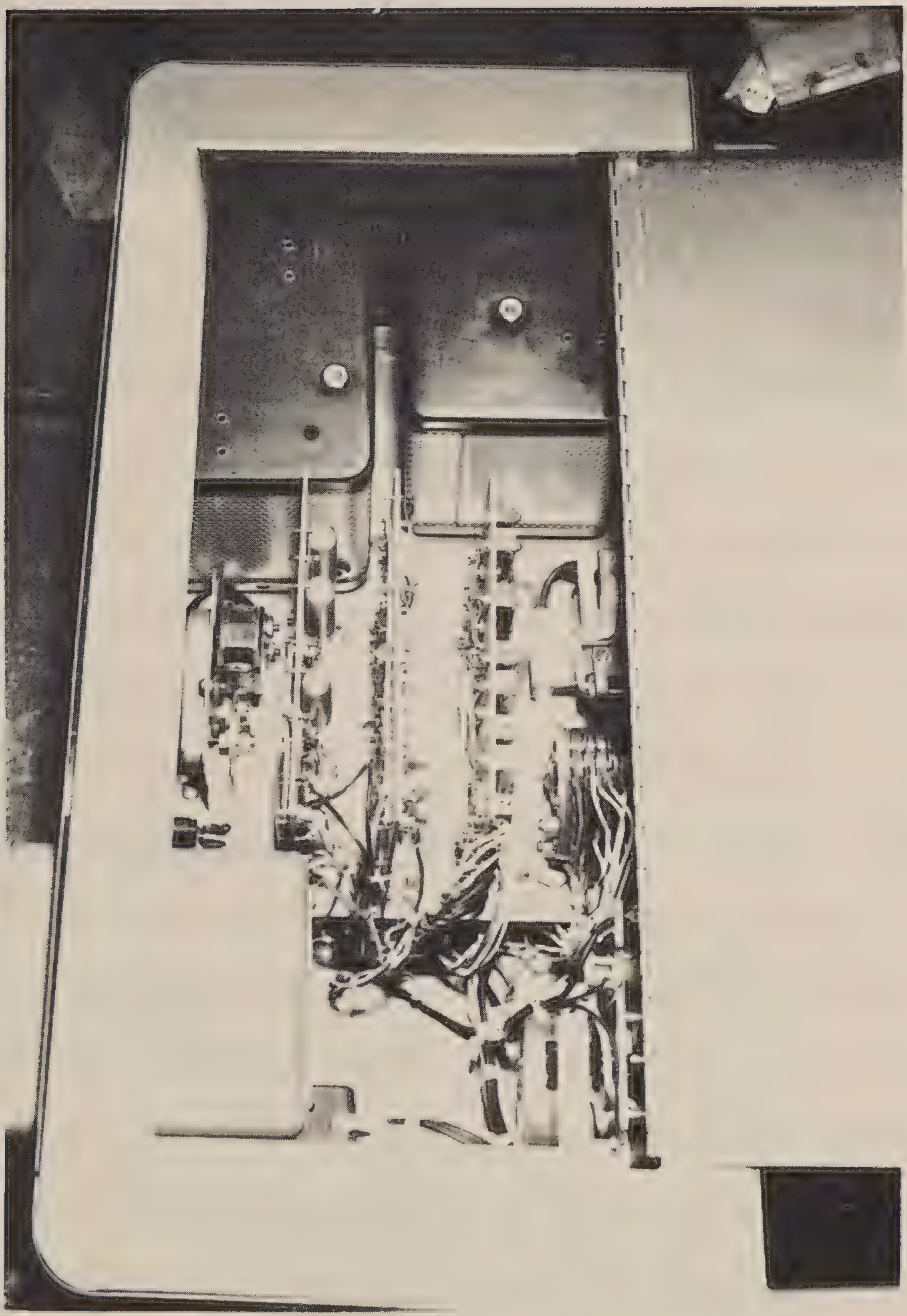

FIGURE 4 - Recorder, top view. Units at top of view are power packs. Center units are (left to right), timer clock, 3 circuit boards, and stepper switch. At bottom of view are Rustrak unit (left) and marker switch.

Mechanical Engineering rig, it was possible to load instruments, supplies and equipment for several installations at once. Although several mechanical breakdowns were experienced with the truck, its use expedited the installation materially, and permitted a considerable saving in installation costs.

Weather Station Components

All eight weather stations are identical (except for wind velocity and direction, which are measured at four stations only). The installations which were standardized as much as local conditions would permit, consist of three units: 1 - the sensing instruments, which at each station are located within a 10-foot square fenced enclosure about 500 feet from the ranch house; 2 - the recorder, containing all necessary electronic circuitry and the strip chart recorder, located in the ranch house; and 3 - the 12 conductor electrical cable, which is strung inside a plastic hose and buried at shallow depth beneath the ground, connecting the sensing instruments to the recorder.

Sensing Instrument Installation - At each station a treated lodgepole pine pole (16 feet long, with 6 inch minimum top diameter) was erected in the center of the 10 foot square instrument enclosure. The pole, which provides support for the louvered thermister shelters and for the anemometers and wind vanes (at the four stations equipped to measure wind), was set in the ground to a depth of four feet. A 9-inch diameter post hole auger, attached to a converted chain saw motor, was used for the digging of holes. A sheet metal cap was fitted over the top of the pole, and a copper grounding wire for lightning protection, running the full length of the pole was attached, before erection of the pole.

The wind speed and direction unit was next installed on top of the pole (at those stations recording wind). The anemometer and windvane had been pre-assembled on a four foot length of 2-inch pipe, and the lower end of the pipe fitted with a pipe flange. The pipe flange was attached to the top of the pole in the field with lag screws. The wind unit is visible in Figure 1, and is shown in greater detail in Figure 5.

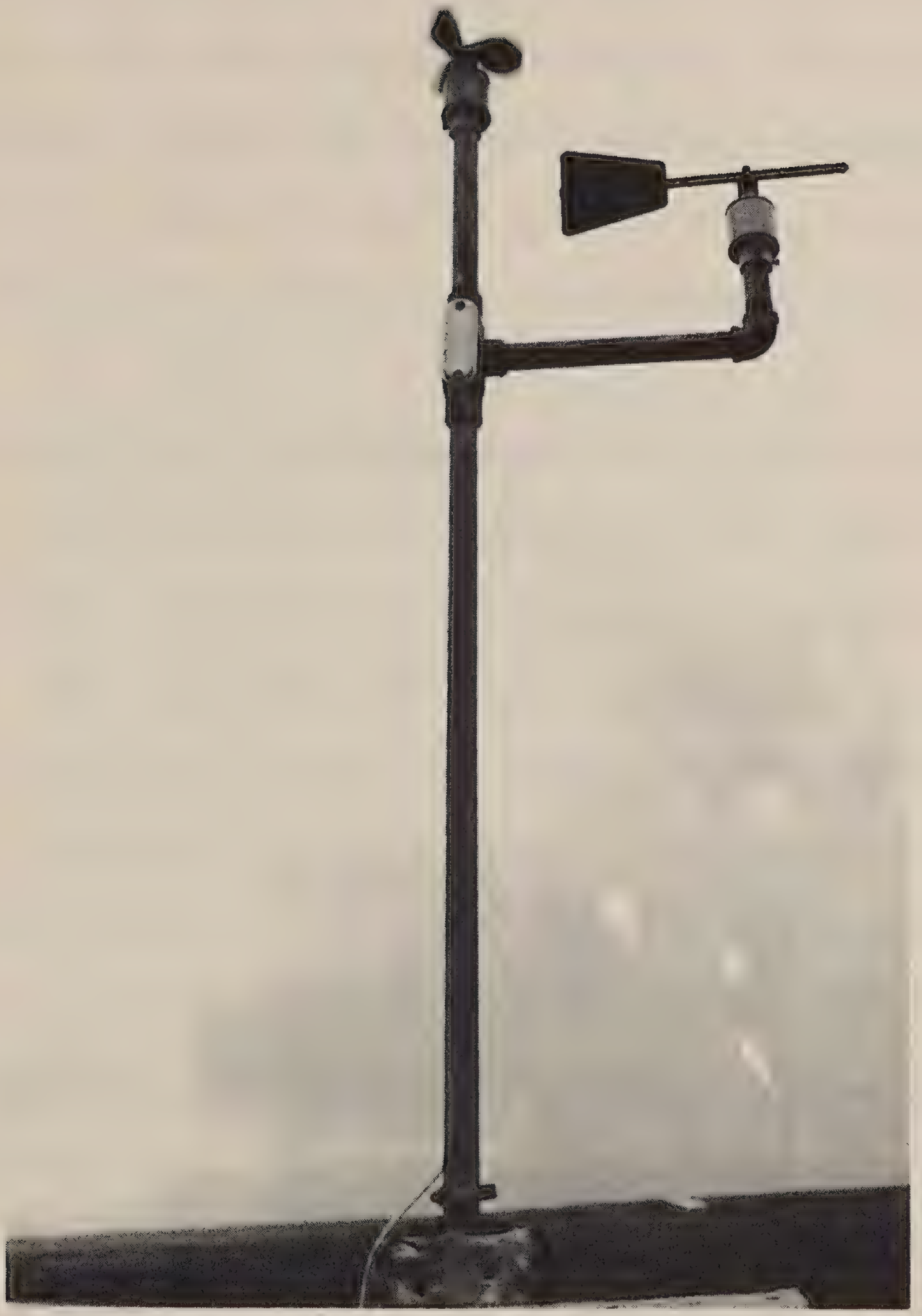

FIGURE 5 - Wind sensing unit atop 12-foot pole. Anemometer is 16 or 17 feet above ground.

The two louvered thermistor shelters were attached to the pole by means of long machine bolts extending through the pole. The shelters were positioned so that the upper thermistor would be located ten feet above ground and the lower thermistor four feet above ground. Since the lower shelter houses the terminal board for all the station wiring in addition to a thermistor, electrical lead wires from the wind system, the upper thermistor, and the soil moisture and temperature units were all fed into the lower shelter and attached to the pre-wired terminal board. Figure 6 shows the interior of the lower thermistor shelter, with the terminal board exposed. The thermistor is visible above the terminal board.

Soil moisture and soil temperature units were installed at three depths at each station. The three-inch depth units are two feet west of the pole, the 9-inch depth units are two feet south and the 18-inch depth units are two feet east of the pole. For each unit, a hole one foot square was excavated to a depth slightly greater than required. Soil samples were taken from the material excavated at the appropriate depth, for later determination of electrical resistance-moisture content relationships. Recesses were hollowed out in one side of each hole at the proper depth, to accommodate the soil thermistor and gypsum block moisture element. Over-excavation of the recesses was held to a minimum. Backfilling of the hole completed the installation. The installation method was intended to provide, insofar as possible, an undisturbed environment for the sensing elements. Except for over-excavation of the recesses that occurred unavoidably, the elements are surrounded by undisturbed soil above and below, and on all but one side.

The instruments are located within a 10-foot square enclosure which consists of a 47-inch high woven wire fence supported by 8 creosoted fence posts. The posts are 6½ feet long, and were set in the ground to a depth of two feet. To simplify bracing of the corner posts, a 2" x 4" wood framework extending around the enclosure was nailed to the tops of the fence posts. A four-foot wide steel walk gate was installed in one side of the enclosure.

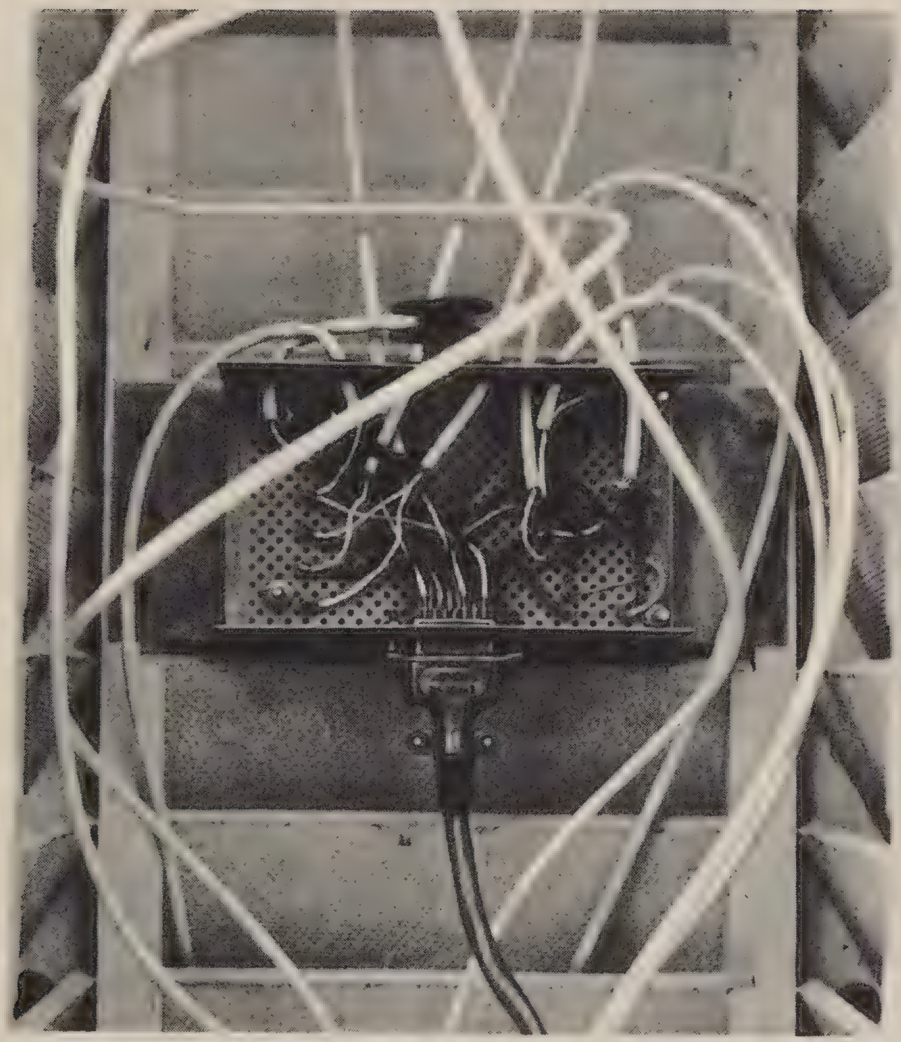

FIGURE 6 - Terminal board inside lower thermistor shelter. (Cover of terminal board removed). Thermistor (temperature sensing unit) is a small bead located between two metal disks above terminal board.

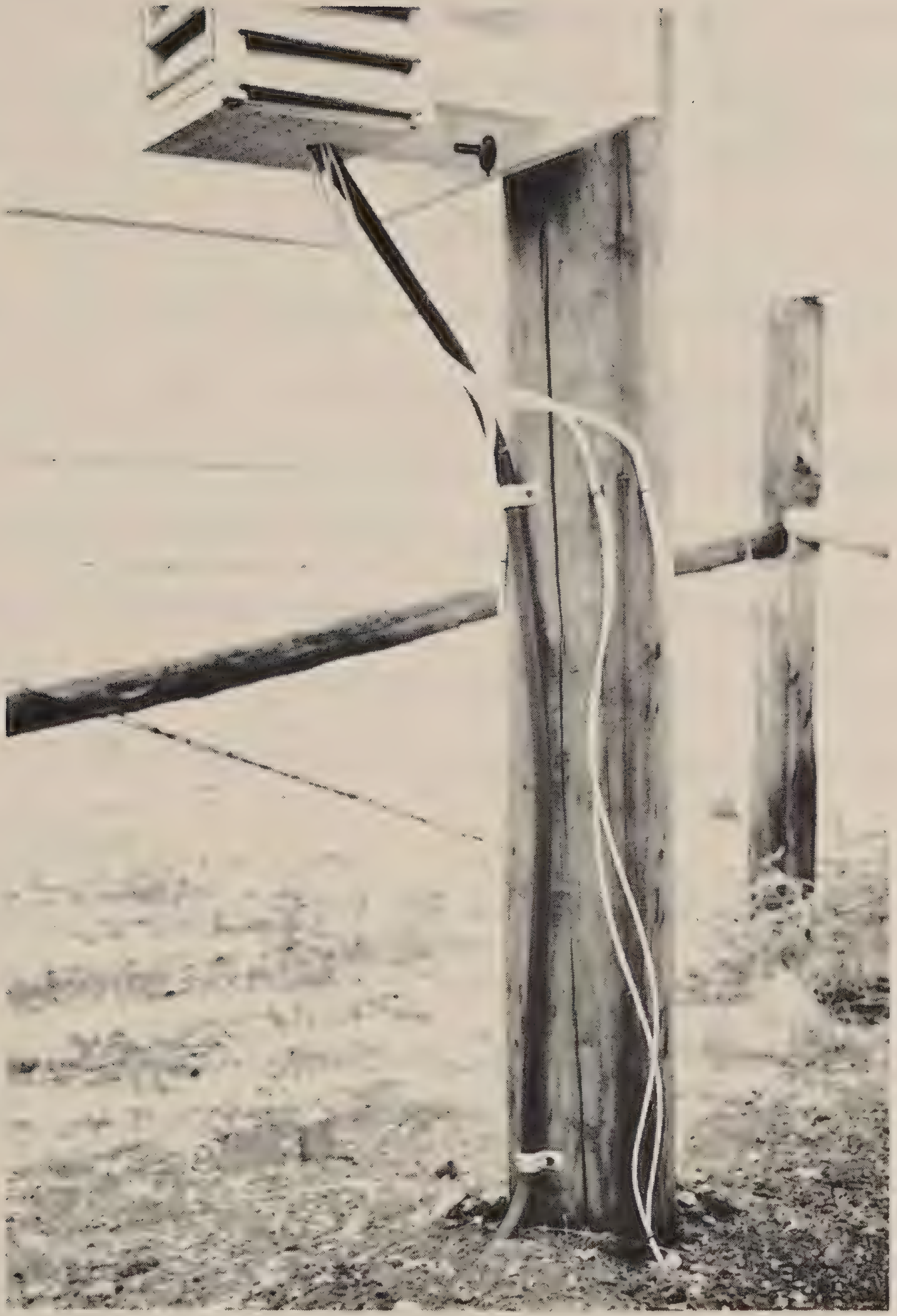

FIGURE 7 - Wiring Detail - 12-conductor wire is strung inside the plastic hose leading from lower thermistor shelter to recorder in ranch house. White wires are leads to soil moisture-temperature units.

All untreated wooden members utilized in the station were painted with white paint.

Recorder Installation

Each rancher-observer was invited to select the spot in his house or basement where he wished the recorder installed. Three of the 8 ranchers selected basement locations, while the rest specified kitchen or utility room sites. The recorders presented few installation problems. All the recorders are identical (except for the omission of certain electronic components on units not measuring wind). The unit occupies a shelf space 18 inches long, 10 inches wide and 10 inches high. Power is supplied by standard 110 volt alternating current, which is available at all stations. The units are equipped with grounded outlet plugs for operator safety, and in most installations this necessitated running an auxiliary grounding wire from a water pipe to the recorder. At several locations a shelf had to be built to accommodate the recorder, and in a few cases power outlets were not conveniently available and had to be installed.

Electric-Wire-Cable Installation - The 12 conductor cable had been pre-strung inside $\frac{1}{2}$-inch plastic hose and cut into 500 foot lengths. One end of each length of hose (with a short length of cable protruding from the end) had been pre-sealed with an epoxy sealing compound. The pre-sealed end was attached in each case, at the instrument enclosure, to the terminal board inside the lower louvered thermistor shelter. The cable was then run to the house, being buried at shallow (6 inch) depth throughout its length. Digging and backfilling the trench required for the cable installation was one of the most time-consuming phases of the entire operation. Figure 7 shows the plastic hose leaving the louvered thermistor shelter, as well as showing wires running to the soil moisture and temperature units.

Entering the house with the cable was accomplished in most cases through a hole either drilled just above the foundation, or dug beneath the foundation. Inside the house, the cable was cut to required length, and the free end of the plastic hose sealed with an epoxy compound.

The electrical cable was thus sealed in a moisture proof environment for its entire buried length.

With the attachment of a connection plug to the 12-conductor wire, the system was ready for connection, and the installation completed.

The weather station distances from the recorder units varied from 275 feet to 525 feet, with 350 feet being the most usual distance. At just one location, the 500 foot length of cable was insufficient, and a splice was necessary. This was at the John Toren ranch at Lone Man Coulee.

A summary of installation details is shown on the next page.

Watershed	Ranch	Location	Wind	[illegible] from House	[illegible] from House	Remarks
Bacon Creek	H.J. Lode	Sec 18, T9N, R15E	Yes	SE	350 ft.	In corner of farmyard. Area essentially level; extensive windbreak west and north of house, but no obstruction within 200 feet of weather station in any direction.
	C.H. Robertson	Sec 10, T8N, R15E	No	South	450 ft.	Along a north-south fence, atop a knoll. Buried cable crosses under a small stream tributary to Bacon Creek. A higher hill rises just west of house, but it is entirely gravel and not typical soil conditions.
Duck Creek	Donald Hauk	Sec 21, T16N, R47E	Yes	West	300 ft.	On a rise in farmyard area, well above housetop. Area is broken and hilly, but site selected is at highest point in immediate vicinity, and is above level of any obstruction.
	Raymond Jonas	Sec 30, T16N, R48E	No	West	300 ft.	On a rise in pasture area, well above housetop. Area is broken and hilly; higher land west of weather station may affect wind from that direction. Otherwise unobstructed.
	Wm. Jordan	Sec 14, T17N, R46E	No	West	250 ft.	Along a north-south fence, in pasture. Area is essentially level. Recorder is in basement of hired man's trailer house. All farm buildings are east and southeast of instruments; no obstruction within 200 ft of weather station.
Hump Creek	G.M. Cain	Sec 27, T2S, R17E	Yes	West	310 ft.	On a rise well above housetop; in pasture land. Rancher has attempted to start a wind break 50 f east of weather station (between station and hou but this has mostly failed. Wind is unobstructe
Lone Man Coulee	James Geiger	Sec 26, T29N, R6W	No	South	350 ft.	Along an east-west fence, in pasture. Area is essentially level. Extensive concentration of t and buildings 300 feet north ofweather station, otherwise no obstructions.
	John Toren	Sec 35, T29N, R5W	Yes	Southeast	530 ft.	Along an east-west fence, in cultivated ground, on a rise well above housetop; a prominent hill lies to the southeast $\frac{1}{4}$ mile from weather statio may affect wind from that direction. Otherwise no obstruction.

V. Instrument Operation

The eight weather stations were all installed in July 1964, and have operated continuously since. Operation and maintenance problems have been relatively few, but are discussed below.

Chart Failure - The most serious operation problem has been failure of the recorder strip chart to advance. The rancher-observers have experienced varying degrees of difficulty in properly installing a new roll of chart paper each month. The trouble stems from the fact that threading of the chart is somewhat complicated, and also from the fact that the chart advance mechanism operates through a clutch arrangement. The clutch causes slippage of the chart when it is mis-threaded, or when it is not properly aligned. There have been very few instances of mis-threading of the chart, but fairly frequent cases of misalignment, which caused clutch slippage. In most cases the loss of data has only amounted to a few hours or a day or two until the observer noticed the problem and corrected it. The only cure for the difficulty seems to be repeated training sessions, to impress upon the observers the need for careful installation of the chart. The cases of chart failure have become less frequent as the observers have become more familiar with the recorders.

Power outage, fuse failure, etc. - It had been feared that power outage would be rather common, because of the long rural lines involved. To date there have been only one or two reports of power outage. The recorders are all equipped with fuses to prevent damage in case of excess power, and one fuse failure has occurred to date. This was during a violent windstorm, and may have resulted from two power lines touching momentarily, causing a line transient.

Miscellaneous - At one station, data reduction revealed the fact that one air temperature and one soil temperature wire had been interchanged at the terminal board at the instrument enclosure during installation. Data from the two instruments involved had to be discarded. Correcting the wiring error eliminated the problem.

VI. Data Processing

Reduction of data from the strip chart records has been maintained at a reasonably current level. Data reduction methods, and problems encountered to date, are discussed below.

The strip chart roll is 2½ inches wide, and 63 feet long, and contains a month's record from one weather station. Signals from the weather instruments are transmitted to the pressure sensitive chart by a stylus which records voltage levels. In operation, the recorder is turned on automatically once every 30 minutes, and scans the eight (or ten) instruments in turn, by means of a stepping switch. The chart advances about ½ inch during each "read-out", so the result is a series of short marks extending the full length of the chart. Samples of data recorded on the strip charts are shown in Figure 8.

Time Identification - As originally installed, the recorders provided no time identification on the chart. However, at each station, the "read-out" is always in the same order. At stations recording wind, the wind speed is always the first signal in the "read-out", and since this signal results from a discharging condenser, the wind speed mark on the chart is transverse instead of longitudinal. For these charts, this provides a positive identification of each "read-out" period. At stations not recording wind, dummy signals are produced to replace the wind speed and direction signals, and the double length mark on the chart identifies the beginning of the "read-out" period. Time identification is thus accomplished by counting "read-out" periods from one end of the chart, and noting the time the observer changed the chart.

Some difficulty was encountered, however, in identifying the time on the charts. In case of a power outage on the ranch, or in case the chart failed to advance for a period, determination of "read-out" time was difficult or uncertain. Marker switches were developed therefore, which could be attached to each recorder, to produce a special identification mark on the chart each night at midnight. A clock on the switch causes a special circuit to be activated for a few minutes

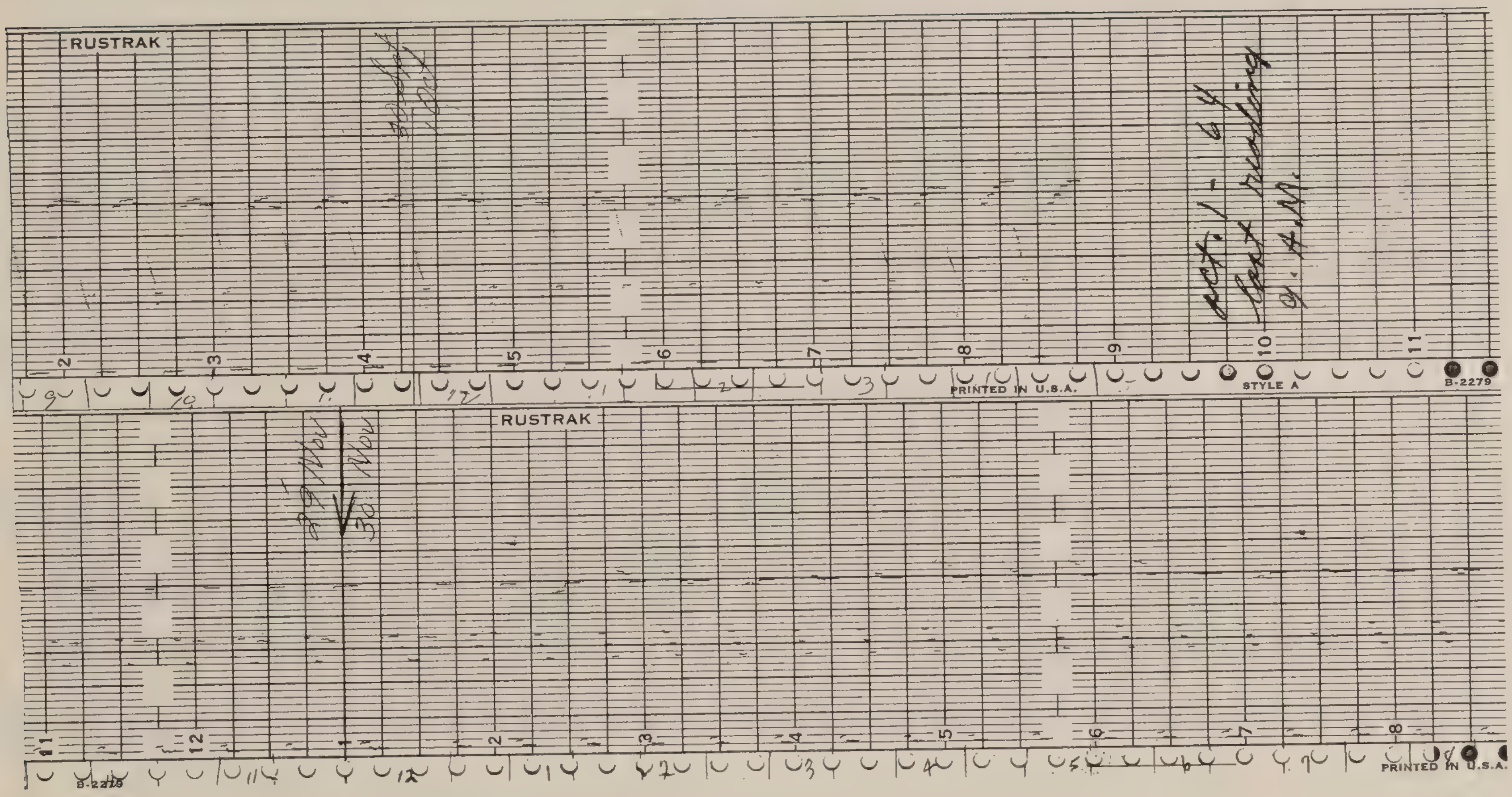

FIGURE 8 - Samples of "read-out," on Rustrak pressure sensitive strip chart. Upper strip is from a station recording wind. Wind speed is denoted by the transverse (vertical) marks. Lower strip is from a station not recording wind. Wind speed and direction marks are replaced by dummy marks at the chart center. Midnight signals are elongated as a result of marker switch installation.

at midnight, and while this circuit is active the speed of advance of the strip chart is doubled. The result is that the midnight "read-out" marks on the chart are double length. With this innovation, time identification is much more positive as well as being simplified. In case of power outage the observer advances the timer to the correct time, just as he would adjust an electric clock. No other attention is necessary on the part of the observer. Marker switches were installed on 3 of the 8 recorders in December 1964, and installation at the other stations was completed in June 1965.

Strip Chart Viewers - To facilitate data reduction, two strip chart viewers were constructed. Made of aluminum and plexiglas, the viewer permits the display of about two feet of chart, and is equipped with spools and cranks at both ends so that the chart may be cranked from either direction. Clear plastic overlays, mounted on each viewer, are imprinted with scales for the various instruments, and by moving the chart beneath the overlay the appropriate values can be readily determined. Figures 9 and 10 show the strip chart viewer and overlay.

Data Reduction - Data reduction is accomplished most efficiently by two men - one to manipulate the chart in the viewer and call out the proper values, the other to record. Recording is done on printed forms, 8½ x 14 inches. Each sheet contains all the data recorded at a single station on one day. The format on the sheet is such that the data may later be transcribed by a key punch operator onto punched cards.

Data Analysis - To date, the data from the weather stations have received only cursory analysis. It is anticipated that computer programs will be utilized in detailed analyses, which are currently being developed.

VII. Conclusion

The preceding report has described the Weather Stations which have been installed on the four watersheds instrumented as part of the Drainage Correlation Research Project. Continuous measurements of wind speed and direction, air and soil temperature, and soil moisture are currently being made at eight locations on the four watersheds.

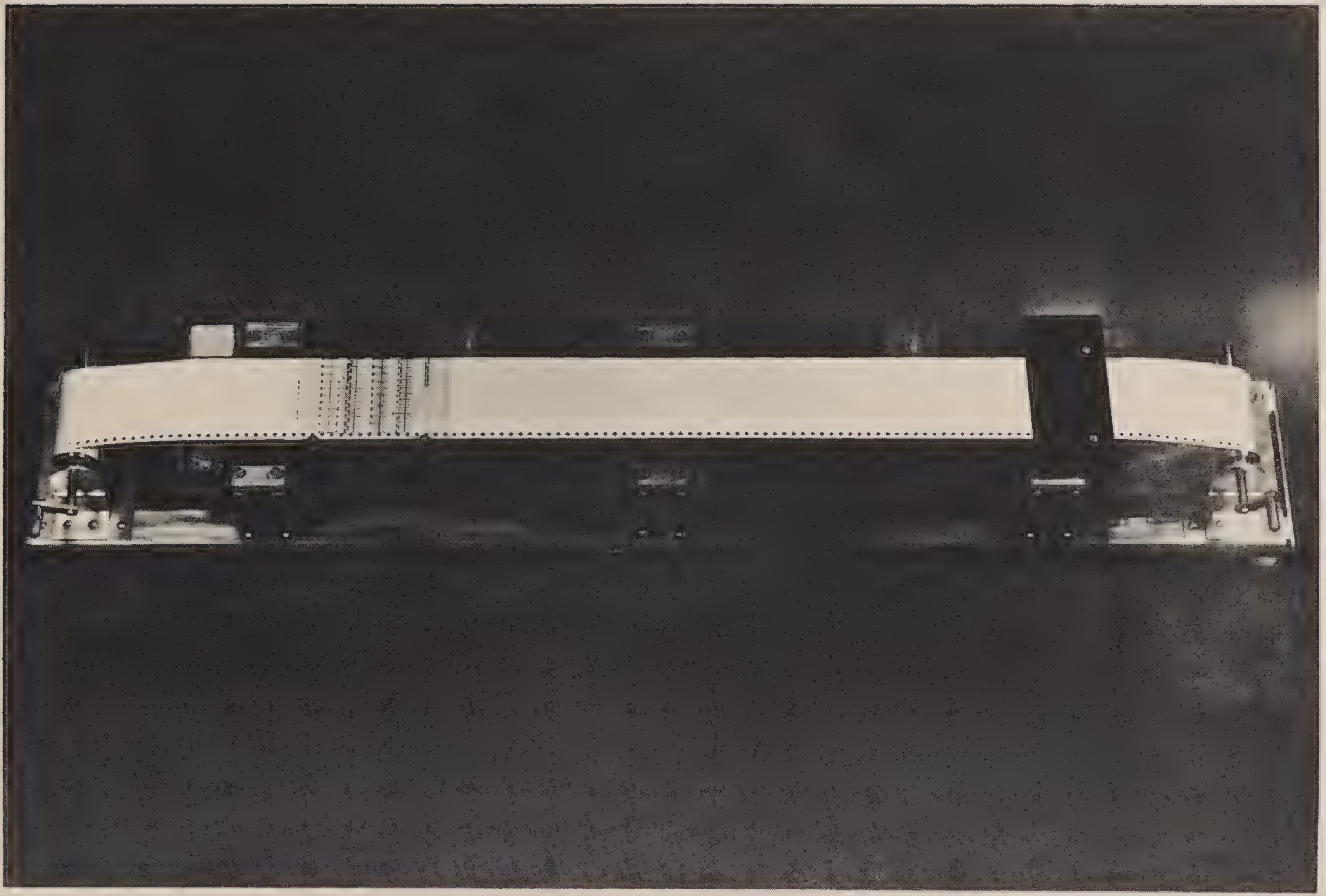

FIGURE 9 - Strip chart viewer, which displays 24 hours record at a time. Strip chart is cranked from either end.

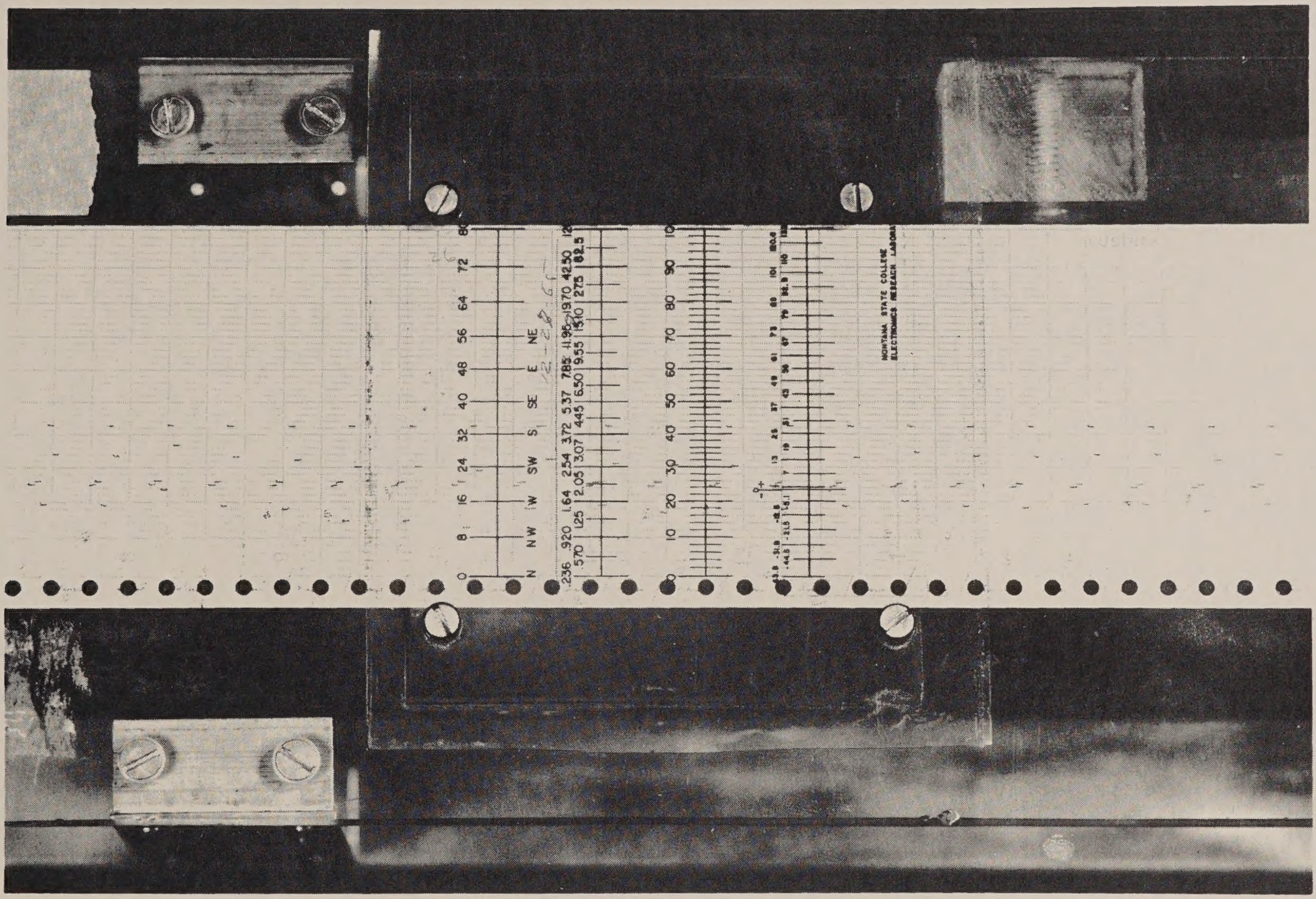

FIGURE 10 - Strip chart viewer, detail. Overlay provides scale reference for the various instruments.

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